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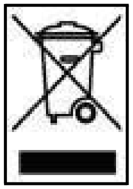
Optical Backscatter Reflectometer 4600

User Guide

CLASS 1 LASER PRODUCT
IEC 60825-1, 2007
AND 21CFR1040.10



Many regions prohibit the disposal of WEEE (Waste Electrical and Electronic Equipment) in the normal waste stream, to comply with the Restriction of Hazardous Substances (RoHS) released into the environment. Please contact your local waste authority for instructions on proper recycling of the electronic product(s) described in this *User Guide*.

Optical Backscatter Reflectometer Model 4600
Versions: *User Guide 6*, OBR 4600 Software 3.12.0

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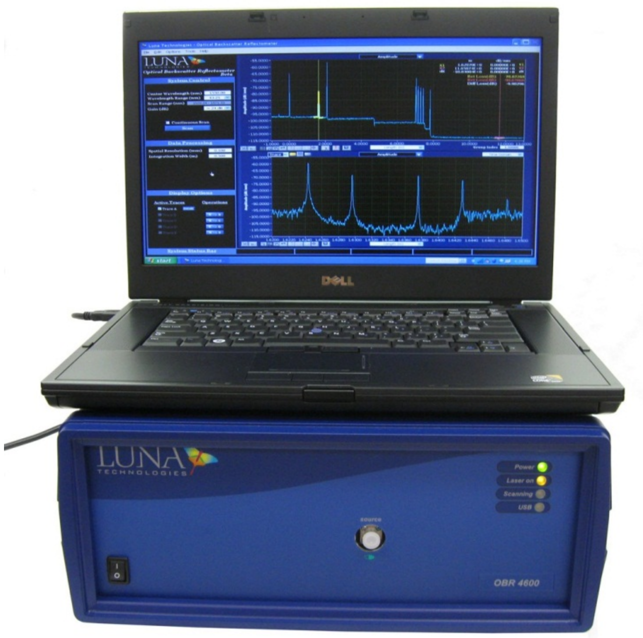
Chapter 1

System Overview

Luna Technologies' Optical Backscatter Reflectometer (OBR) is the industry's first ultra-high resolution reflectometry device with backscatter-level sensitivity for interrogating components or systems. The OBR uses swept-wavelength coherent interferometry to measure minute reflections in an optical system as a function of length. This technique measures the full scalar response of the device under test (DUT), including both phase and amplitude information.



Data is presented graphically, providing the user with unprecedented optical-module inspection and diagnostic capabilities. The data may be used to:

1

- **Locate loss events**—Monitor backscatter levels to isolate losses due to bends, crimps, bad splices, etc.
- **“Look inside” devices**—Use high resolution and sensitivity to interrogate individual components within a subsystem.
- **Track Polarization**—Track changes in the state-of-polarization as light propagates through an optical network.

The Control Software

The OBR control software includes an intuitive graphical interface (Figure 1-1). All controls, options, and measurement results are easily accessible from the single main window or the menu bar. The user selects which parameters are displayed from the pull-down menu at the top of either plot window.

Caution

Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure and one or more safety protections may be impaired or rendered ineffective.

The following parameters are calculated and displayed by the OBR control software:

Time Domain Data (Upper or Lower Graph)

- Amplitude (dB/mm) (For a complete definition, see “Time Domain Amplitude and Amplitude (dB)” on page 180).
- Amplitude (dB) (See page 180).
- Linear Amplitude (See page 181).
- Phase Derivative (See page 182).
- Polarization States (See page 181).
- Magnitude Difference (See page 182)

Frequency Domain Data (Lower Graph)

- Return Loss (See page 168).
- Linear Amplitude (See page 166).
- Polarization States (See page 166
- Group Delay (See page 169).

Distributed Sensing Options (Lower Graph)

The following time domain parameters are only available to users who purchase spectral shift or **Distributed Sensing** options with the OBR.

- Magnitude Difference (See page 182)
- Spectral Shift (See page 175).
- Spectral Shift Quality (See page 190)
- Temperature Change (See page 174).
- Strain (See page 174).
- Temporal Shift (See page 175).

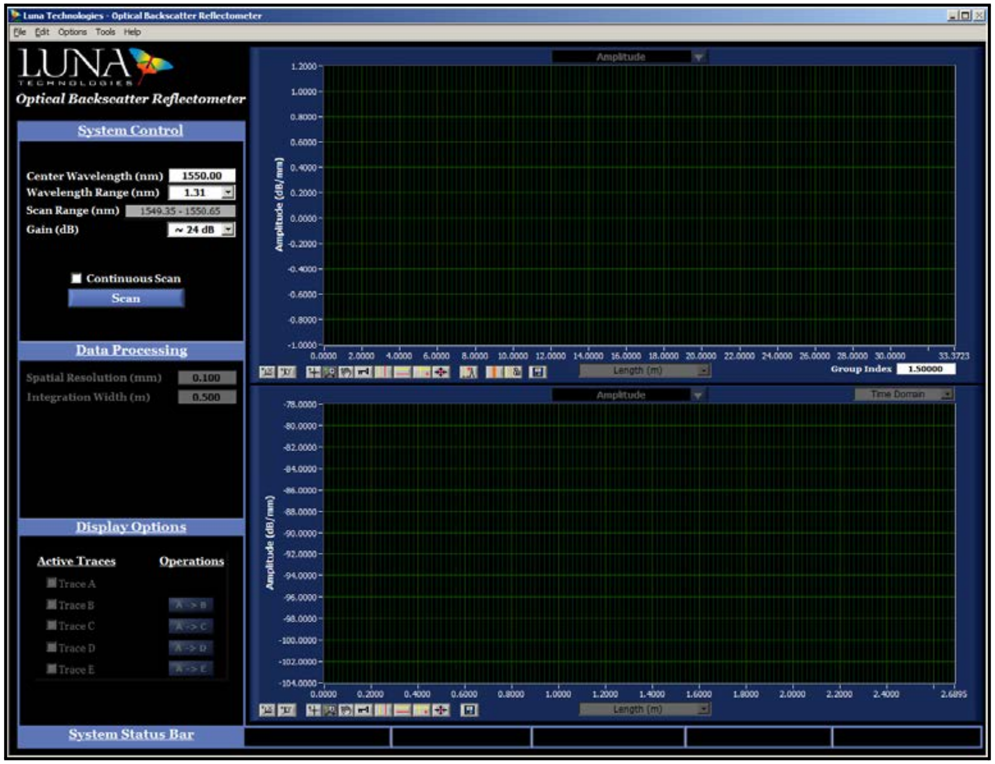


Figure 1-1. Control software main window. Some of the buttons and fields will be "grayed," or inactive when the software starts. They become active when data is loaded or scanned into the software.

1

The control software also provides many tools for data acquisition, manipulation, and display. Data may be acquired in standard, spot, or fast scan in continuous or regular scan mode. Postprocessing allows the user to change the spatial resolution without the need to redo the measurement. Graph windows support powerful zoom and cursor features.

Time Domain Data

By default, the upper graph displays the amplitude of the time domain data, which is equivalent to a traditional optical time domain reflectometry (OTDR) measurement. The user may also set the lower graph to display time domain data by using the pull down graph in the upper right hand corner of that graph.

In the time domain, each optical interface within the device under test produces a peak. The time domain data can also be displayed in terms of length. This allows the user to quickly and reliably identify and locate reflections along the length of an optical system. The phase derivative of the time domain data can also be displayed in the upper plot window. The phase derivative corresponds to the instantaneous wavelength response of a device. This is particularly useful for devices designed to operate over narrow wavelength bands like DWDM (dense wavelength division multiplexed) filters.

The return loss shown in the upper graph gives the single average loss value at each vertical cursor, for a quick pass/fail evaluation for each optical path or interface.

Frequency Domain

By default, the lower plot shows the linear amplitude of the frequency domain data, which corresponds to the insertion loss or return loss of the device under test. The lower plot can also display return loss, polarization states, or group delay.

The frequency domain plot is calculated based on only the time domain data highlighted by the cursor in the plot window above. Therefore it is possible to analyze individual sections of a device or system and determine the amplitude and phase response of each interface separately, by highlighting their corresponding peaks in the time domain plot. This provides a powerful means for quickly and easily identifying faults and pinpointing their cause within a component, module, or subsystem.

Frequency Domain Resolution

The duration of the impulse in the time domain determines the necessary step size for the group delay measurement. If the step is too large, information about the device is lost. If the step is too small, extraneous noise enters the measurement. Luna Technologies' OBR software allows the user to select precisely the correct step size by setting the time domain window so that it includes only the device response. It is also possible to obtain group delay data for a variety of step sizes by changing the setting of the time domain window and recalculating the frequency domain data. There is no need to perform a new measurement. This contrasts traditional methods of group delay measurement, such as the modulation phase shift technique, where the user must guess at the appropriate step size and perform a new measurement to change that step size.

1

Chapter 2

Assembly and Startup

The Optical Backscatter Reflectometer is shipped with everything needed to conduct device characterizations, including the measurement instrument and all supporting hardware, software, documentation, and cables.

Read and follow all assembly and startup instructions before attempting to operate the Optical Backscatter Reflectometer.

Warning

The protection provided by the equipment may be impaired if the equipment is used in a manner not specified by the manufacturer, resulting in serious injury or death.

Components List

The Optical Backscatter Reflectometer is shipped with either a laptop or a PC with monitor, keyboard and mouse. All other components shown below are shipped with each OBR instrument.

Optical Backscatter Reflectometer 4600 instrument.

One (1) USB cable to connect the OBR instrument to the PC

2

One (1) power cord for the OBR instrument. (Plus two (2) more, if you ordered the PC and monitor)

OBR laptop PC (or desktop PC, shown below)

Laptop power supply

OBR desktop PC (or laptop PC, shown above)

17-inch flat panel monitor (with desktop only)

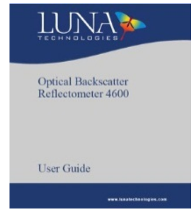
Monitor-PC interface cable (with desktop only)

Keyboard (with desktop only)

Mouse (with desktop only)

Gold reflector

2



This *OBR 4600 User Guide*

Software recovery CD-ROM

Optical fiber connector cleaner

Optical fiber bulkhead connector cleaners

If components are missing or damaged, contact Luna Technologies toll free at 866-586-2682 or by e-mail at support@lunatechnologies.com.

Setting up the OBR

Important

The instrument should always be fully assembled before turning power on to any of its components.

2

To set up the OBR

1 Remove all the OBR components from the shipping containers and verify that no components are missing. (See “Components List” on page 7.)

2 For best performance, place the OBR on a stable surface, capable of supporting the weight of the entire unit. For the weight and dimensions of the unit, see Appendix A, “Specifications,” on page 213.

Important

Place the OBR away from walls or objects that will restrict the air flow through the fan duct on the back of the unit.

3 Unpack and set up the desktop or laptop PC according the manufacturer’s instructions provided. If you purchased a desktop PC, connect the monitor, keyboard, and mouse to the PC, using the cables provided. For user-supplied PCs, see “Minimum PC Requirements” on page 204.

Important

Do not turn on to the PC yet.
Do not connect the instrument to the PC until instructed.

Do not place the laptop on top of the instrument.

4 If printouts are desired, connect a local printer to a printer port (parallel or USB) on the PC using the proper cable for the printer, according to the PC manufacturer instructions enclosed. For information on printing from the OBR software, see “Printing Graphs” on page 76.

5 If necessary, install the drivers for local or network printers that will be used for printing data sheets.

Important

Do not install any software on the OBR PC other than a printer driver or software supplied by Luna Technologies.

Third-party software installed on the PC may impair the proper function of the OBR.

6 Optional: To connect the OBR to a network, connect a network cable (not provided) to the ethernet port on the PC.

7 ***Do not connect*** the OBR instrument to the PC with the USB cable until instructed in the next section.

8 On the front of the instrument, there is a white plastic cap installed to protect the source port. Leave this cap on when the instrument is not in use. To remove the cap for measurements, turn the white cap counterclockwise.

9 Attach the power cords provided to the instrument and to the PC. To ensure safe operation, place the instrument to allow easy disconnection of the power cord. Note that the OBR requires surge-protected, grounded outlets.

Initial Startup

1 After full assembly above, turn on the PC (according to manufacturer's instructions), allowing it to fully load up Microsoft® Windows® 7 or XP. (Note that the screen appearance shown in this *User Guide* may vary according to Windows® version and options.)

2 If you purchased a PC from Luna Technologies, it comes with the OBR control software already installed. If not, install the OBR software now. (From the Luna Technologies CD provided, open the OBR 4600 folder and run setup.exe, following on-screen instructions.)

3 Ensure that the OBR is powered **OFF**.

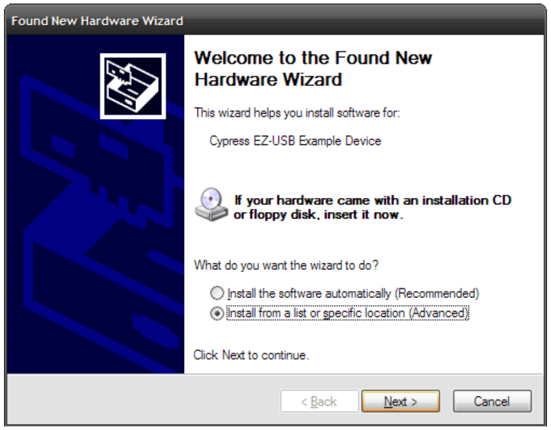
4 Connect the OBR to the PC using a standard USB cable (provided).

5 Turn on the OBR using the power switch on the front panel.

6 All LEDs on the front panel of the instrument will turn on, then all but the **Power** LED will turn off. The **Power** LED will remain lit until the unit is powered off.

7 The PC will automatically detect the device and display the “Found New Hardware Wizard” dialog window:

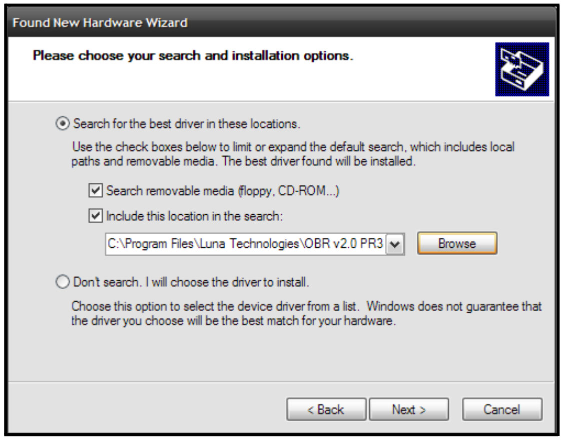
8 Select the “**No, not this time**” option and click the “**Next**” button to continue. A new window will be displayed:



2

9 Select the "**Install from a list or specific location (Advanced)**" option and click the "**Next**" button.

10 A new window, similar to the one below, is displayed:

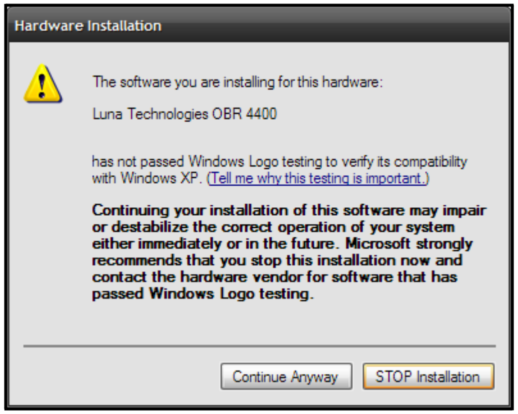


11 Select the "**Search for the best driver in these locations**" option and check the "**Include this location in the search**" checkbox. Click the "**Browse**" button to select the location of the driver.

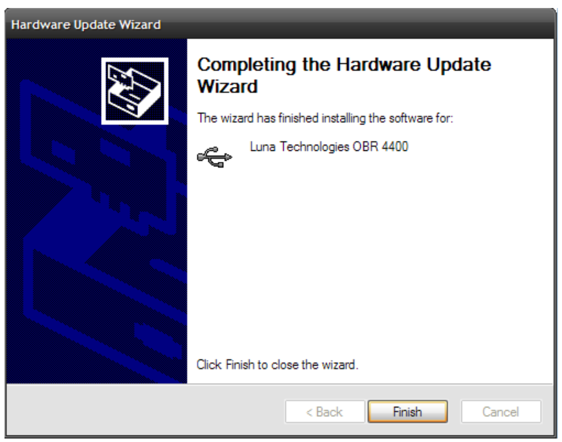
12 Browse to the location where the instrument software was installed (e.g. C:\Documents and Settings\All Users\Application Data\Luna Technologies\OBR v#.#) and then into the "USB_Drivers" sub-directory. Click "**OK**".

13 Another dialog box will alert the user to wait while the Wizard searches. When it becomes available, click the "**Next**" button to continue.

14 An alert dialog will be displayed:



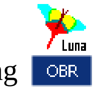
15 Click the "**Continue Anyway**" button to proceed. A new window will be displayed:



16 Click the "**Finish**" button to complete installation of the driver.

Important

It is helpful to make a note of which USB port you used for the OBR instrument. If the instrument is ever connected to a different USB port, it may require that this driver installation procedure be completed again.

17 Start the control software by double-clicking  the **OBR** desktop icon or by selecting **OBR Software** from the programs group in the Windows® Start menu. An initial window will appear for a few moments while the user interface is initialized.

Important

If the control software is started when the instrument is not powered on, a communication failure error message opens. However, the software can be used in desktop analysis mode when the instrument is not powered by clicking **OK** in the message box.

To operate in normal mode (which is required for scanning), turn on the instrument and then restart the OBR software.

Once the control software is running, the OBR is ready to Acquire Reference. (See “Instrument Configuration” on page 34, and “Calibrating the System” on page 35.) Any time the equipment stabilizes to a new ambient temperature (anywhere between 10–40 ºC) the user may wish to perform another **Reference Scan** for greater accuracy.

Chapter 3

Software Guide

The control software is the primary interface between the user and the instrument. It provides all of the necessary tools to reference the system and to perform precise loss and reflection measurements of fiber-coupled optical devices. It also contains a variety of powerful features for data manipulation and display.

This chapter provides an overview of the location and function of all controls and indicators included in the control software. Chapter 4, “Performing Measurements,” on page 33 provides greater detail on how to use the OBR to perform specific measurement tasks. Chapter 5, “Data Processing and Display,” on page 59 more fully describes how to process the data and manipulate plots.

Important

If the control software is started when the instrument is not powered on, a communication failure error message opens. However, the software can be used in desktop analysis mode when the instrument is not powered by clicking **OK** in the message box.

To operate in normal mode (which is required for scanning), turn on the instrument and then restart the OBR software.

Window Features

Figure 3-1. OBR control software main window, with data loaded. Note that the upper vertical cursors are on, so loss calculations are shown in the upper graph. The sensing features and shift reference displayed in the ***Data Processing*** *and* ***Display Options*** *areas are not available on all OBR units. The number of traces available also depends on OBR configuration.*

The main window is composed of 6 functional areas:

1 The **System Control** area contains buttons to control the OBR instrument and set test parameters.

2 The **Data Processing** area allows the user to enter the desired the spatial resolution and **Integration Width**. When **Options > Sensing** is enabled

(if purchased) the fields in this area change. (See “Distributed Sensing Measurements” on page 48.)

3 The **Display Options** area allows the user to control which traces are being displayed, to move data within local memory, and to view the **Details** of each measurement loaded into memory. This will be further explained under “Displaying Multiple Traces” on page 59.

4 A **System Status Bar** message will light up if saturation or overheating is detected. They are shown in the normal, “off” status in Figure 3-1 above. If one of these lights, see “System Status Bar Messages” on page 203.

5 The two **Graph** areas may contain plots of test data, as described in the next section. The upper graph displays time domain data, and the lower displays either time domain or frequency domain data. The pull-down menu at the top of each graph allows the user to select which parameter is displayed. Buttons to the lower left on each graph adjust plot axes, cursors, legend, and zoom.

6 The **Menu Bar** contains additional commands for loading and saving data files, printing, performing reference scans, and for setting various measurement and display options. (See “The Menu Bar” on page 27.)

System Control

The **System Control** area of the main window contains fields and menus that control the OBR instrument and set test parameters, as shown on the left. If **Extended Mode** was purchased, the **System Control** will have one of two appearances, depending on the **Options > Distance Range** setting.

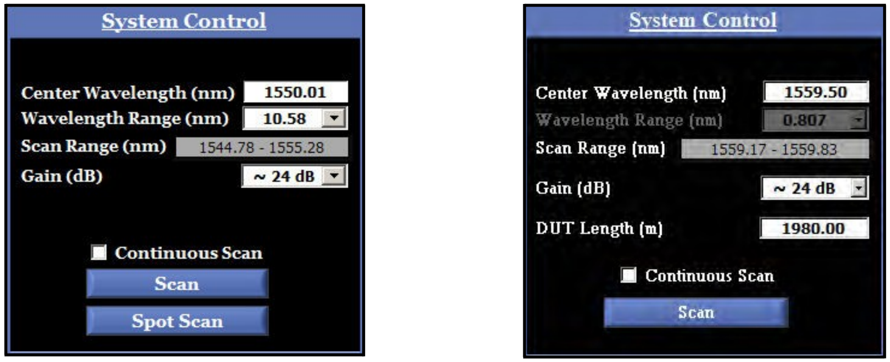


*Figure 3-2. The **System Control** area in the main OBR software window, shown in **Normal** (left) and **Extended** (right) **Distance Range** modes. Also in the left example, **Spot Scans** have been enabled by turning on the **Spot Scan Cursor**.*

- The **Center Wavelength (nm)** field allows the user to set the center wavelength of a scan. To set this parameter, type in a number within the wavelength range of the instrument.
- The **Wavelength Range (nm)** field allows the user to set the range of the scan. The wavelength range determines the number of nanometers that will be analyzed during the next measurement. A drop-down list contains the range options available for the OBR model in use. This value cannot be changed when operating in **Extended Range** mode (see “Instrument Configuration” on page 34).
- The **Scan Range (nm)** field shows the starting and ending wavelengths that will be scanned, as determined by the center wavelength and wavelength range entered by the user (or by default) in the two fields above.
- The **Gain (dB)** field allows the user to select the gain of the scan from a drop-down list of options.
- **Continuous Scan**, when checked, causes the OBR to take repeated measurements. The graph displays are continuously updated after each measurement. This mode is started and stopped by pressing the **Scan** button.
- Clicking the **Scan** button starts the measurement of the device under test. This same button is used to stop scanning when operating in **Continuous Mode**.

- Clicking the **Spot Scan** button (as shown in the left side of Figure 3-2) starts a spot measurement of the device under test. (See “Spot Scan Mode” on page 44.) This same button is used to stop a **Spot Scan** when operating in **Continuous Mode**.

Data Processing

The **Data Processing** area allows the user to enter **Spatial Resolution** and **Integration Width** settings, as shown on the left below. For more information, see “Spatial Resolution Calculations” and “Integration Width” on page 164. If the **Distributed Sensing** option was purchased, and **Options > Sensing Enabled** is **ON** (checked), the **Data Processing** area changes to allow setting of sensing parameters, as shown on the right below. (See “Distributed Sensing Measurements” on page 59.)

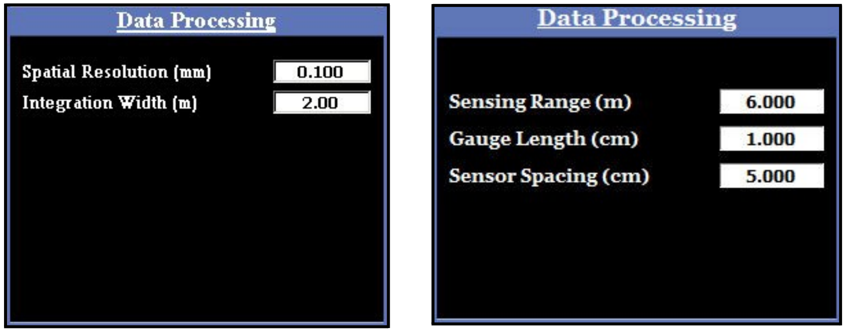


*Figure 3-3. The **Data Processing** area in the main OBR software window when **Options > Sensing Enabled** is **OFF** (left) or **ON** (right).*

Display Options

The **Display Options** area allows the user to store data from the most recent scan to one of two or more traces, depending on your unit’s configuration. The data loaded in a given trace may be graphed by clicking in the adjacent checkbox. It may be moved from **Trace A** to another trace by clicking a button in the **Operations** column.

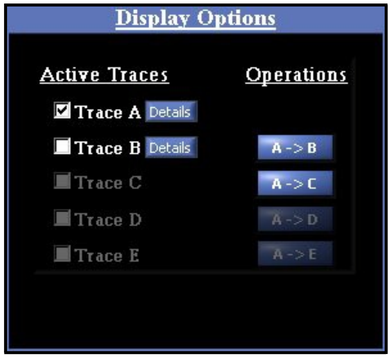


*Figure 3-4. The **Display Options** area in the main OBR software window. Only two traces will be available when the OBR is turned off (desktop analysis mode), and with some high resolution configurations.*

If the Distributed Sensing option was purchased, the last **Trace** will also be labeled as the **Shift Reference** (See “Distributed Sensing Measurements” on page 59) when **Options > Sensing Enabled** is **On** (checked).

Graphs

Each **Graph** area contains controls for selecting the content of the graph and for manipulating how the graph is displayed.

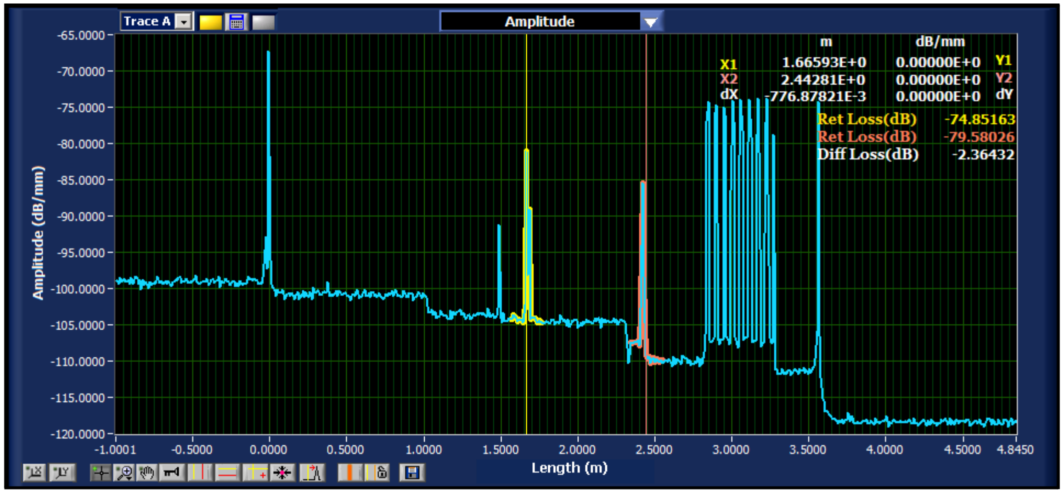
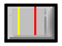


Figure 3-5. The upper graph area in the main OBR software window.

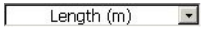
- The upper graph will display newly scanned or loaded data.
- Two conditions allow data to appear in the lower graph:

  Standard Scan Mode: First, the vertical cursors  must be turned on in the upper graph. Second, *either* **Options > Display Options > Auto-Update Lower Graph** must be turned on (checked), *or* the user must click the recalculate button  at the upper left of the upper graph. Controlling the content of the lower graph will be covered more fully under “Updating Lower Graph” on page 67.

  Spot Scan Mode: Data will also appear in the lower graph during continuous spot scans if the upper vertical cursors are on (see “To perform continuous spot-scan measurements” on page 46).

- The **Title Bar** at the center top of each graph contains a pull-down menu allowing the user to select which parameter is graphed. These parameters are defined under “Standard Parameter Calculations” on page 179.

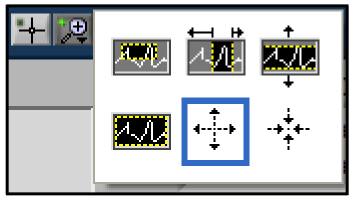
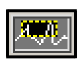
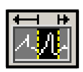
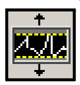
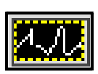
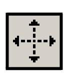
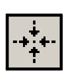
*Figure 3-6. The parameters menu on the left is available for the upper graph. The menu on the right is the **Time Domain** menu for the lower graph area. The last five parameters will be gray (unavailable) in some models. By selecting **Frequency Domain** in the top right corner of the lower graph area, the menu shown in the center becomes available.*

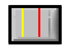
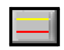
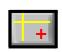
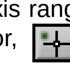
- The pull-down menu 

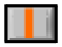
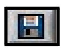
 at the bottom of a time domain graph allows the user to select the value and units of the X-axis: **Time (ns)**, **Length (m)**, **Length (ft)**, or **Length (in)**. In the lower frequency domain graphs, the available X-axis units are **Wavelength (nm)**, **Frequency (GHz)**, and **Frequency (THz)**. Note that the Y-axis units are determined by the parameter displayed.
- **Buttons** to the lower left of each graph let the user adjust plot axes, cursors, and zoom, and show or hide a legend. Table 3-1 describes the function of each button and gives a page number for further explanation.

Table 3-1: Graph area buttons and their function.

Button	Description	Page
	Sets the scale of the X-axis to display the full range of the data set.	69
	Sets the scale of the Y-axis to display the full range of the data set.	69

Button	Description	Page
	Sets the mouse cursor to a cross-hair that allows the user to drag graph cursors.	72
	Allows the user to select from the following zoom tools that appear in a pop-up menu. A blue border surrounds the selected tool.   Allows the user to click and drag to define a “zoom window” in both the X and Y dimensions.  Allows the user to click and drag a zoom area in the X-axis only. This is the default tool active in each graph.  Allows the user to click and drag a zoom area in the Y-axis only.  Returns the graph to the full scale of all data.  Zooms in (magnifies) from the point where the cursor is located.  Zooms out from the point where the cursor is located.	70
	Lets the user pan around the data in a graph window by clicking on the graph and dragging the cursor.	74

Button	Description	Page
	Toggles two vertical cursor lines on or off. Note that when these cursors are on in the *upper* graph, differential and return loss are calculated and displayed in the upper right legend. Also, the data points integrated to calculate loss are highlighted in contrasting colors. By default, with all cursor buttons, cursors are attached to **Trace A**. The user may attach them to another trace using the pull-down menu  at the upper left corner of the graph. Note that with all the cursors, the X- and Y-coordinates are displayed in the upper right of the graph when any cursors are on.	73
	Toggles two horizontal cursor lines on or off.	73
	Toggles the plot legend on or off. The color, style, and width of a line may be changed in a menu accessed by clicking within the legend. (See “Changing graph style and color” on page 74.)	74
	Toggles twin locked cursor on and off. Regardless of where these cursors are dragged, they will intersect the first graph at a data point.	73
	Brings cursors into the viewed portion of the graph. By default, cursors appear at 10% and 90% of the X- or Y-axis range. They may be dragged by selecting the cross-hair cursor, .	73
	Moves the vertical cursors to the peak of the regions highlighted. This control only works properly with vertical cursors, when **Options > Cursors > Show Integration Area** is enabled (checked) [When **Options > Sensing Enabled** is on, this menu item becomes **Options > Cursors > Show Sensing Area**. See “Distributed Sensing Measurements” on page 48.]	73

Button	Description	Page
	Allows the user to set the location of subsequent spot scans.	45
	Locks the spot scan cursor onto the active cursor.	45
	Saves the current graph as a .jpg image file.	57
 	The center button recalculates the data in the lower graph area based on the data in the upper graph highlighted by the yellow (left) or orange (right) vertical cursor. These buttons appear in the upper left of the upper graph only when the vertical cursors are on in the upper graph. Clicking the left button will automatically recalculate the lower graph based on the yellow cursor in the upper graph *if* **Options > Display Options > Auto-Update Lower Graph** is checked. Otherwise, the user must click either the yellow or the orange button and then hit the recalculate (center) button. The pull-down menu to the left of these buttons shows which trace is being displayed in the lower graph.	67

The Menu Bar

The menu bar contains additional commands for performing reference scans and for setting various measurement and display options. Menu bar commands are organized into five menus.

The File menu

- **Load Data File** loads a binary data file (of the type ".obr") previously saved by the OBR. A dialog box appears allowing the user to select the file.
- **Save Data Files** saves measurement data according to the selections in the **File** > **Select File Options** dialog box. (See "To save data" on page 65 for more information.)

- **Load Reference File** allows the user to select a file from the hard drive to load into the shift reference. (See “Distributed Sensing Measurements” on page 59.) This feature is only available as a purchased option, and will otherwise be gray in the file menu.
- **Select File Options** calls up a dialog box allowing the user to select the file type(s) for data saved. The user may select the file extensions for spreadsheets (.txt) and binary files (.obr). Only binary files may be reloaded into the OBR software. (See “Saving Data” on page 62 for more information.)
- **Save Software Options** saves user-selected settings from the **Options** menu; these options are retained the next time the software is run.
- **Print Datasheet** prints the two graphs as they are displayed to the default printer. (For more information, see “Printing Graphs” on page 76.)
- **Exit** exits the OBR control software.

The Edit menu

- **Cut** may be used to cut user-selected numbers in fields and axes and paste them to the clipboard.
- **Copy** copies selected numbers from a field or axis to the clipboard.
- **Paste** pastes numbers from the clipboard to a field or axis value.

The Options menu

- **Instrument Configuration** calls up a dialog box where the user can select the device length range (in **Normal Range** mode) and the desired resolution. (See “Instrument Configuration” on page 34.)
- **Distance Range** allows the user to select either **Normal Range** (30 or 70 m) or **Extended Range** (up to 2 km) measurements. This menu item is gray if the user has not purchased the **Extended Range** option. The user should note that the spatial resolution will go down when operating in the **Extended Range** mode. (See the Specifications Sheet that came with your OBR unit for details.)
- **Resolution BW Units** allows the user to select either picometers (pm) or gigahertz (GHz) as the resolution bandwidth units. The default setting is picometers. The resolution bandwidth is displayed in the *lower right* of the *lower graph area*, but only when the *upper*

vertical cursors are on and when the *lower graph* displays frequency domain data. Data resolution is further discussed under "Resolution Bandwidth Calculations" on page 177.

- **Data Decimation (Upper Graph) > Specify Level** allows the user to select data decimation level, as explained under "Data Decimation" on page 75.
- **Display Options** controls several display features:

  > Auto-Update Lower Graph, when checked, automatically recalculates the lower graph whenever new data is loaded or scanned, provided the upper vertical cursors are on.

  > Apply Spatial Resolution Filter turns on (checked) and off (unchecked) the time domain filter. (See "Spatial Resolution Calculations" on page 178.)

  > **Apply Frequency Domain Window** turns on (checked) and off (unchecked) the Frequency Domain Window. (See "Frequency Domain Windowing" on page 47.)

  > Autoscale Y Axes (Both Graphs) allows the user to turn on (default setting) and off autoscaling for the Y-axes in both graphs. When this option is selected, the plot axes automatically scale to include the entire data set on the Y-axes when a new measurement is performed.

  > Autoscale X Axis (Upper Graph) or **(Lower Graph)** allows the user to turn on and off autoscaling for the X-axis in the upper or lower graph.

- **Cursors** > **Show Integration Area**, when checked (default setting), highlights the data points used to calculate the data for the lower graph. [In **Distributed Sensing Mode** (page 48), a purchased option, this menu item will read **Options > Cursors > Show Sensing Area**, though it will function the same.] When the **Integration Area** (or **Sensing Area)** is shown, return loss and differential loss are displayed in the upper right corner of the upper graph.
- **Spot Scan:**

  > **Logging Enabled** turns on (checked) and off (unchecked) the automatic saving of data files during **Continuous Spot Scanning**. The directory and file prefix are set through the next menu item, **Options > Spot Scan > Set Logging Options**.

>**Set Logging Options** calls up a dialog box where the user may set the directory and filename prefix for logged data.

- **Fast Scanning:**

  > **Fast Scanning Enabled** turns on (checked) and off (unchecked) fast scanning. See “Fast Scan Mode” on page 44.

  > **Set Fast Scan Rate** calls up a dialog box for setting the scan rate, as described further under “Fast Scan Mode” on page 44.

- **Sensing:**

  > **Sensing Enabled** turns on (checked) and off (unchecked) distributed sensing, if this option was purchased. Otherwise this menu item will be gray. (See “Distributed Sensing Measurements” on page 48.)

- > **Temperature and Strain Coefficients** calls up a dialog box where the user can change the values used to convert from spectral shift to temperature change and strain. For more information, “Temperature Change and Strain Coefficients” on page 49.
- **Lower Graph:**

  > One Plot, when checked, means one parameter at a time will be plotted in the lower graph.

  > Two Plots, when checked, brings up two parameter selection menus in the lower graph area. For more information, “Displaying Two Parameters in Lower Graph” on page 66.

- **Color Palette** calls up a dialog box allowing the user to specify the colors for each graph. These changes may be saved for future times the software is used (by clicking **Save**), or only be applied to the current use of the software (by clicking **Apply**). Clicking **Reload Defaults** allows the user to go back to the original software settings.
- **Remote Interface Setup** calls up a dialog box to set up remote configuration. For more information, see Chapter 7, “Controlling the OBR Remotely,” on page 119.

The Tools menu

- **Turn Laser OFF** or **ON** allows the user to turn the laser on or off from the OBR control software.

- **Calibrate** calls up a dialog box which allows the user to specify the calibration settings and begin a calibration. (See “Calibrating the System” on page 35 for complete calibration instructions.)
- **Align Optics** performs an alignment of the internal optics of the OBR. See “Aligning the OBR Optics” on page 34 for more information about system alignment.
- **Calibration Information** calls up a screen with information on the laser calibration currently in use.
- **Specify Calibration Filenames** allows the user to use the default calibration filename (obrCal_refl), or to uncheck this box and type in or select a new calibration filename. For further details, see “Calibration Files” on page 36.
- **Reload Calibration Data** reloads the most recent valid calibration data. This may be used when a calibration fails or is cancelled by the user.
- **Install New Feature Key** calls up a dialog box where the user may enter a key string provided by Luna Technologies, in order to unlock a newly purchased software feature.
- **Reset Hardware** allows the user to reset the OBR hardware without having to turn off the device. This should only be used in the rare event that the device becomes non-responsive. This command will close the software and thus requires the user to restart the OBR software.

The Help menu

- **About OBR 4600** displays information about the current software version and contact information for Luna Technologies.
- **Version Information** calls up a dialog box showing the OBR hardware version. This information is used by Luna Technologies for upgrading OBR hardware.

3

Chapter 4

4

Performing Measurements

Setting Up

The front panel of the Optical Backscatter Reflectometer contains the power switch and the optical connector necessary to perform reflection measurements.

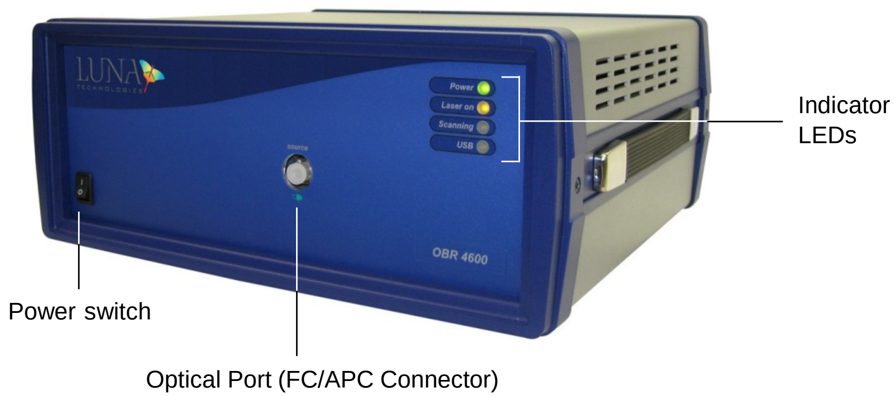


Figure 4-1. The OBR 4600 instrument.

Four LEDs indicate the state of the instrument:

- The **Power** LED lights when the power is on.
- **Laser On** lights after the laser has been turned on.
- **Scanning** lights whenever the laser is scanning.
- **USB** lights after a scan, while the OBR unit is sending data to the PC.

Aligning the OBR Optics

In order to perform accurate measurements, the internal optics of the OBR must be properly aligned. The three conditions that require an alignment to be performed are listed below.

Alignment must be performed...

1 When the instrument is initially set up for the first time.

2 Whenever the OBR is physically moved from one location to another.

3 Whenever the **Out of Alignment** indicator in the **System Status Bar** is visible.

To align the OBR optics

1 Ensure that the OBR unit is powered on and that the laser is on and ready.

2 Select **Tools** > **Align Optics**.

A dialog box appears instructing the user to disconnect devices. The user may opt to **Cancel** or click **OK** to continue.

If **OK** is selected, alignment begins. A status bar shows the progress of the alignment. When the alignment is complete, the software returns to the main window.

3 The user must next perform a calibration, as described below.

Instrument Configuration

Before calibrating the instrument, the user should select **Options** > **Instrument Configuration**. This calls up a dialog box (Figure 4-2) where the user can select the maximum device length for **Normal Range** measurements. (In **Extended Range** mode, selecting the maximum device length has no effect.) The user can also select the desired resolution level.

The right side of this dialog box shows the **Resultant Values**, based on the length and resolution settings. With higher resolution data, only 2 traces are available. Length and resolution settings also determine the maximum wavelength range available, which is also shown in this box.

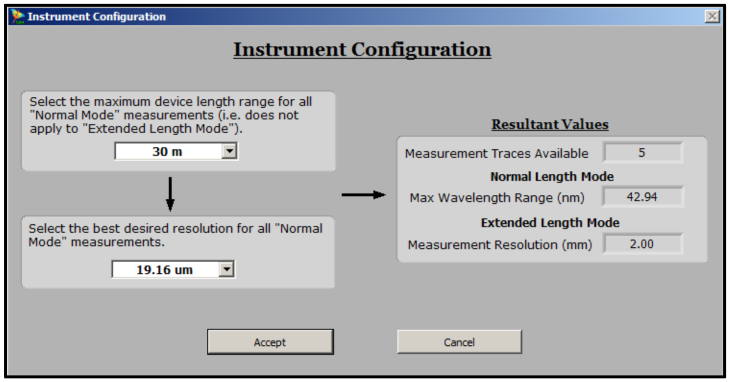


*Figure 4-2. The **Instrument Configuration** dialog box allows the user to set the maximum device length and resolution, and shows the resultant wavelength range and number of traces available.*

Changing the desired resolution in the lower left pull-down menu (Figure 4-2) may require a software restart, depending on how much the settings change. However, a dialog box (Figure 4-3) will appear allowing the user to continue and close the software, or to cancel the resolution change.

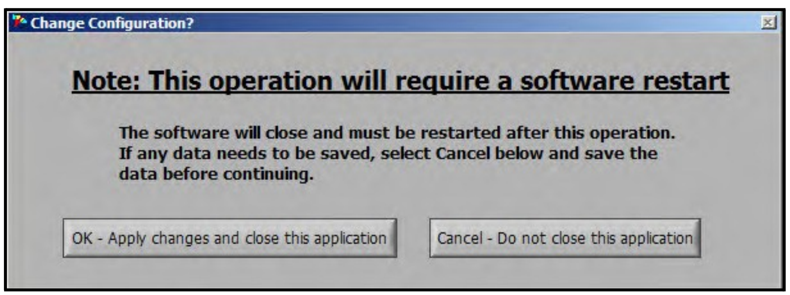


*Figure 4-3. This dialog box appears if a change in resolution requires a software restart. The user can opt to continue (**OK**) or **Cancel** the resolution change.*

Calibrating the System

The OBR system must be calibrated prior to performing measurements. The OBR calibration removes the effects of the measurement network to ensure that the measured data represent only the device under test.

Calibration Files

The most recent calibration is stored in a file which is loaded by the control software upon start-up. If the software is unable to locate a calibration file, a dialog box will appear to alert the user that a calibration must be performed before a measurement can take place. In this event, the **Scan** button will be unavailable (gray) until a calibration has been performed.

Conditions that Require Calibration

In a typical laboratory or manufacturing environment, calibration should be performed at least once every 24 hours. The need to recalibrate is largely determined by the surrounding environmental conditions. If the temperature is fluctuating rapidly, it may be necessary to calibrate more than every 24 hours. If the surrounding temperature is very stable, a longer interval may suffice.

Calibration should be performed whenever the surrounding temperature has changed by more than ± 5 degrees C. And as already mentioned, the OBR must be calibrated after an alignment.

In certain cases the control software will detect that the internal optics of the instrument have drifted, and it will alert the user via the **System Status Bar** indicator 

. When this occurs performing a calibration will typically suffice.

Consideration Prior to Calibrating

The maximum spatial resolution that can be achieved with the OBR is related to the wavelength range of the measurement according to

$$\Delta z = \frac{\lambda_1 \lambda_2}{n_{eff} \Delta\lambda},$$

where Δz is the spatial resolution, n_{eff} is the effective index of refraction of the device under test, λ_1 and λ_2 are the start and end wavelengths of the scan, and $\Delta\lambda = |\lambda_1 - \lambda_2|$. Thus, calibration over larger wavelength ranges will allow for the highest spatial resolution measurements.

The Calibration Procedure

To calibrate the system

1 Ensure that the OBR unit is powered on and that the laser is on and ready. The **Laser On** light on the front of the instrument comes on when the laser reaches operating temperature.

2 Select **Tools** > **Calibrate**.

The following dialog box appears:

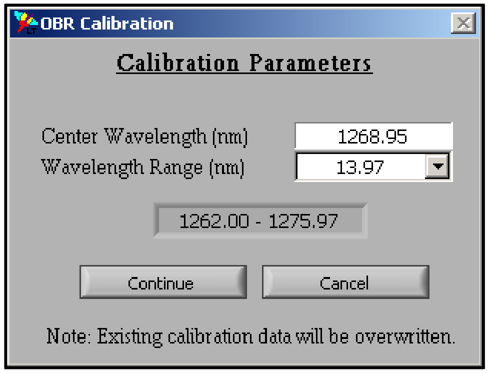


Figure 4-4. ***Calibration Parameters*** *dialog box.*

3 Type in the **Center Wavelength** appropriate for the device(s) to be tested following calibration.

4 Select the desired **Wavelength Range** from the pull-down menu.

Note that in order to perform measurements over a broader wavelength range than the one selected during calibration, it is necessary to recalibrate.

5 Click **Continue**.

The instrument performs several internal scans. Next a prompt appears instructing the user to connect the supplied reference fiber and reflector to the instrument. *First follow step six.*

6 Before making connections, be sure to clean all fiber optic connectors. (See “Cleaning Connectors” on page 195.)

7 Align the connector key to fit in the groove in the bulkhead adaptor. Turn the screw ring around the connector clockwise until it is just tightened.

8 Click **OK**.

A dialog box appears as calibration proceeds.

9 A prompt appears instructing the user to disconnect the reference fiber and reflector. After doing so, click **OK**.

10 Click **OK** in the dialog box indicating that the instrument has been successfully calibrated.

After calibrating, it is advisable to check if the calibration was successful, to ensure that the system will provide accurate data.

Checking the Calibration

1 Follow all the instructions above, under “To calibrate the system” on page 37.

2 Reattach the gold reflector, after cleaning its connector.

3 In the **System Control** area, enter a **Center Wavelength** and select a **Wavelength Range** from the pull-down menu. These settings must fall within the range of the calibration just performed or currently loaded.

4 Click **Scan**.

The instrument performs the measurement and the software displays the test data in the upper graph.

5 From the parameters menu or **Title Bar** in the upper graph, select **Amplitude**. This may already be displayed, as it is the default setting.

6 Turn on the vertical cursors in the upper graph by clicking .

7 Select the cross-hair tool, then click and drag the yellow cursor to about 1.0 m, the location of the gold reflector.

8 Click the button, which moves the cursors to a local peak.

9 In the **Data Processing** area, set **Integration Width** (or **Sensing Range**) to 0.2 m.

10 In the lower graph **Title Bar** area, click the yellow [button icon] button, meaning that the lower graph will be calculated based on the upper, integrated segment surrounding the yellow cursor.

11 Next hit the blue [button icon] recalculate button in the lower graph **Title Bar** area.

12 Select **Frequency Domain** from the pull down menu at the upper right of the lower graph.

13 From the lower parameters menu or **Title Bar**, select **Return Loss**.

14 The resulting curve should be nominally flat, within the measurement accuracy of the instrument, with a mean value of about 0.0 to -1.0 dB. (For the return loss accuracy see the Specifications Sheet shipped with your OBR unit.)

If the return loss curve is *not* nominally flat, perform a second calibration. If this fails to yield a nominally flat return loss curve, contact Luna Technologies toll free at 866-LUNAOVA (866-586-2682).

Storing Multiple Calibrations

Users may store more than one calibration file, covering different wavelength ranges. Note that users should only use calibration files created in the last 24 hours or so, as explained under “Conditions that Require Calibration” on page 36.

To store or use multiple calibrations

1 Select **Tools > Specify Calibration Filenames**. The dialog box below appears.

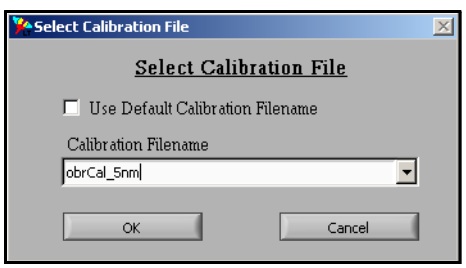


*Figure 4-5. **Specify Calibration Filename(s)** dialog box.*

2 Click on the **Use Default Calibration Filename(s)** checkbox, leaving it unchecked, as shown above. The **Calibration Filename** field becomes accessible.

3 Type in a new filename. Alternately, if other calibration files have been saved, the user may select a previously-saved calibration file from the pull-down list. The default calibration filename is obrCal_refl.

4 Click **OK**.

5 If you typed in a new calibration filename, next select **Tools** > **Calibrate**. Follow the instructions under “The Calibration Procedure” on page 37. The new calibration will then take effect. It will be stored under the filename entered in the **Specify Calibration Filename(s)** window shown above.

—OR—

If you selected an existing calibration file, you must select **Tools** > **Reload Calibration Data**. Or, if you wish to overwrite this existing filename with a new calibration, simply perform a new calibration.

In either case, the OBR will not warn you if you are overwriting an existing calibration file.

6 In order for the current calibration file to take effect when the OBR software is restarted, select **File** > **Save Software Options**. Otherwise, the default calibration file (obrCal_refl) will be loaded upon the next startup.

Important

Again: Renaming the calibration filename under **Tools > Specify Calibration Filenames** *does not* change the calibration file used by the OBR software. To do so, the user must next perform a new calibration, or select **Tools > Reload Calibration Data**.

Acquiring Data

The OBR has several options for data acquisition: **Single Scan Mode** and **Continuous Scan Mode**. Both modes can be performed at user-controlled speeds (see “Fast Scan Mode” on page 44) and in user-selected regions of the fiber under test (see “Spot Scan Mode” on page 44 and “Extended Range Spot Scan Mode” on page 46). Each option performs a complete scalar measurement of the device (or section of the device, for **Spot Scans**) under test, and all parameters are available from measurements done in any mode.

Important

Before attaching any device, clean the fiber optic connector with the appropriate cleaner to guard against errors. For instructions, see “Cleaning Connectors” on page 195.

Single-Scan Mode

The single-scan measurement represents the basic functionality of the OBR. In this mode the instrument performs a single sweep of the laser over the selected wavelength range, and acquires data for the device under test over that range.

To perform a single-scan measurement

1 Ensure that the OBR unit is powered on and that the laser is on and ready. The **Laser On** light comes on when the laser reaches operating temperature. Launch the OBR software.

2 Be sure that the instrument has been aligned (see “To align the OBR optics” on page 34), configured (see “Instrument Configuration” on page 34), and calibrated (see “To calibrate the system” on page 37) within the recommended time period.

3 Before connecting the device to the OBR, be sure to clean all fiber optic connectors. (See “Cleaning Connectors” on page 195.)

4 Connect the device to the **Source** port on the front of the OBR.

5 Enter an appropriate **Center Wavelength** in the **System Control** area (Figure 4-6).

If the center wavelength entered falls outside the range of the instrument, the software replaces it with a value within the instrument’s range. (See the Specifications Sheet shipped with your OBR unit for standard instrument wavelength ranges.)

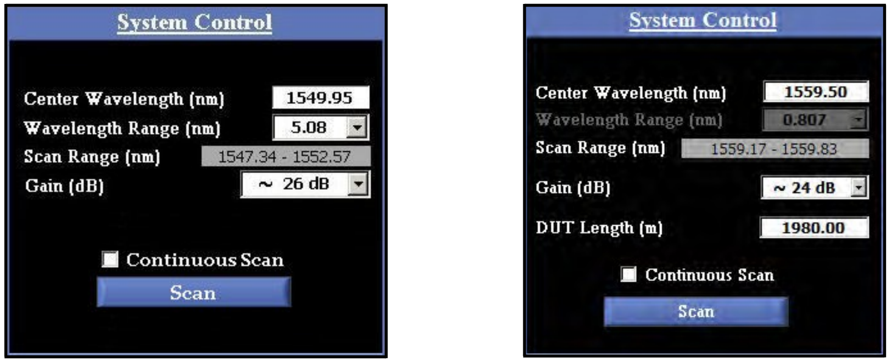


*Figure 4-6. The **System Control** area in the main OBR software window, shown in **Normal** (left) and **Extended** (right) **Distance Range** modes.*

6 *In **Normal Range** mode*, select a **Wavelength Range** from the pull-down menu. If the desired scan range falls outside the range of the most recent calibration, either select a smaller scan range or recalibrate the OBR.

*In **Extended Range** mode*, the **Wavelength Range** is set by the software, depending on the resolution set by the user (see “Instrument Configuration” on page 34). As mentioned earlier, **Extended Mode** is not available unless purchased as an option.

7 *In **Extended Range** mode*, enter the **DUT** (Device Under Test) **Length** in meters. When measuring near the end of the range of DUT Length, it is important to enter an accurate DUT Length, ±20 m. At the beginning of the **Distance Range**, accuracy within 100 meters is sufficient.

8 Check the **Options > Display Options** menu for functions to be applied to the scan, such as **Data Decimation** (see page 58) and **Auto-Update Lower Graph**. These options may also be applied to data after scanning. However, to apply **Frequency Domain Windowing** to the data, it must be turned on before scanning (see page 42).

9 If **Distributed Sensing** options were purchased, you may wish to adjust the **Options > Temperature and Strain Coefficients** (see “Distributed Sensing Measurements” on page 48).

10 Click **Scan** in the **System Control** area (Figure 4-6).

The instrument performs the measurement and the software displays the test data in the upper graph.

Note that even if **Options** > **Display Options** > **Auto-Update Lower Graph** is off (unchecked), data may appear in the lower graph window from a previous scan. To update the lower graph based on the current time domain data, see “Updating Lower Graph” on page 67.

Continuous Scan Mode

Continuous scan mode takes advantage of the fast measurement speed of the OBR to monitor devices whose properties may change slowly with time.

Important

For accurate measurements, the device must change slowly enough that its properties remain constant while data is acquired.

Note that continuous scan mode will operate more quickly if the lower graph area is “turned off” by unchecking **Options** > **Display Options** > **Auto-Update Lower Graph**. To view this data after scanning, see “Updating Lower Graph” on page 67.

To scan continuously

1 Perform all but the last step of a the **Single Scan** mode above. Before clicking the **Scan** button, select **Continuous Scan** in the **System Control** area of the main window.

2 *Optional*: To gain more speed, uncheck **Options** > **Display Options** > **Auto-Update Lower Graph**.

3 Click **Scan** in the **System Control** area (Figure 4-6).

4 The **Scan** button will turn gray during continuous scanning.

The active graph window(s) will update after each scan.

5 To stop scanning, either press the grayed **Scan** button again, or uncheck the **Continuous Scan** box above the **Scan** button.

Fast Scan Mode

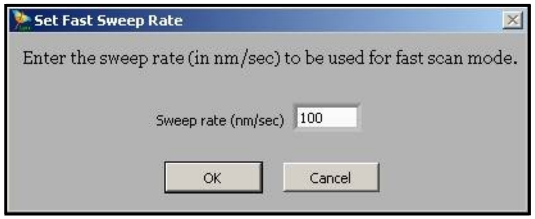
In both the **Single Scan** and **Continuous Scan** modes, the user may chose to increase the scanning rate from the default setting. **Spot Scans** (see below) may also be performed at a user-set scanning rate.

The user should note that **Fast Scanning** increases the laser sweep rate to decrease measurement time. **Fast Scanning** is not appropriate for some applications with high return loss. The **Fast Scan** sweep rate can be set from 10 to 200 nm/sec.

Note

In order to increase the laser sweep rate, the laser acceleration range must also be increased. This reduces the maximum available wavelength range to avoid low wavelength values. To achieve a larger wavelength range in **Fast Scan** mode, the user **may need to recalibrate with a higher center wavelength**. Calibrating the instrument while in Fast Scan mode will coerce the center wavelength to values that are valid for the Fast Scan mode.

1 Before clicking **Scan**, select **Options > Fast Scanning > Set Fast Scan Rate**. In the dialog box shown below, set the scanning rate.



2 Select **Options > Fast Scanning > Fast Scanning Enabled**. (A check mark in the menu indicates that **Fast Scanning** is **On** or **Enabled**.)

3 Perform a **Scan** as instructed under "Single-Scan Mode" on page 41 or "Continuous Scan Mode" on page 43.

Spot Scan Mode

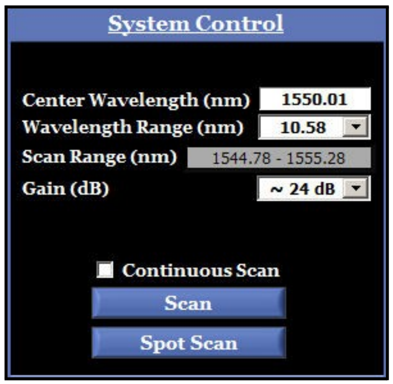
The **Spot Scan** mode allows the user to scan a one- to two-meter region of the DUT, allowing for shorter measurement times and smaller data files. **Spot Scans** may be performed in both the **Single Scan** and **Continuous Scan** modes, at default or user-set scanning speeds.

To perform a single spot-scan measurement

1 If desired, select **Options > Fast Scanning > Set Fast Scan Rate** to set the scanning rate.

2 A regular scan must be completed prior to performing a spot scan. Follow the instructions under “To perform a single-scan measurement” on page 41.

3 Click the **Spot Scan Cursor button**: . Note that a **Spot Scan** button will now appear in the **System Control** area, as shown below.



4 Select the cross-hair tool , then click and drag the broad, orange **Spot Scan Cursor** to a region of interest in the data for a spot scan, and release the cursor.

5 Click the **Spot Scan** button in the **System Control** area. The resulting **Spot Scan** will be displayed in **Trace A** in the upper graph area.

6 Click the X-axis scale tool to display the full range of the data set.

To perform continuous spot-scan measurements

1. Follow the instructions above for a single **Spot Scan**. In the **System Control Area**, click to enable **Continuous Scan** mode.

2. *Optional*: If **Data Logging** is desired, select **Options > Spot Scan > Logging Enabled**. (A check mark in the menu indicates that **Logging** is **On** or **Enabled**.)

   Select **Options > Spot Scan > Set Logging Options**. In the dialog box which appears, browse to select the directory for logged data. Enter a file prefix and click **OK**. A separate data file will be saved for each **Spot Scan** in the selected directory.

3. In order to display **Continuous Spot Scans** in the lower graph, turn the vertical cursors on in the upper graph. (See “To update the lower graph” on page 67.) Drag the yellow cursor to the **Spot Scan** region. Alternatively, you can press the spot scan lock button  to lock the spot scan cursor to the active vertical cursor. (See “Spot Scan Cursor Unlocked or Locked Toggle Button:” on page 74.)

4. Click the **Spot Scan** button to start continuous scanning. This button will turn gray during continuous scanning. **Continuous Spot Scans** will appear in the lower graph.

5. To stop scanning, press the grayed **Spot Scan** button again

Extended Range Spot Scan Mode

Just as with spot scans in regular mode, this method of scanning provides measurement data over a sub-section (more than 85 m) of the extended range scan in a fraction of the time it takes to perform a standard extended range scan. *The scan rate in this mode is set to 10 nm/s, with Fast Scanning currently disabled in this mode*. Larger wavelength range scans are available when performing spot scans. This provides measurement data with a 4x increase in spatial resolution. The **Extended Range** mode allows the user to scan devices out to 2 kilometers in length. **Extended Range Spot Scans** may be performed in both the **Single Scan** and **Continuous Scan** modes.

To perform extended range spot-scan measurements

1 Perform the first four steps of the single **Spot Scan** measurement (see “To perform a single spot-scan measurement” on page 45). Select **Options > Distance Range > Extended** (A check mark in the menu indicates that **Extended Range** is **On** or **Enabled**). As mentioned earlier, **Extended Mode** is not available unless purchased as an option.

2 *In **Extended Range** mode*, a standard extended range scan must be performed prior to performing any extended range spot scans. See the instructions on performing a standard extended range scans (see “Single-Scan Mode” on page 41 which includes Extended Range scan instructions).

3 *In **Extended Range** mode*, the **Wavelength Range** can be increased from the minimum available when performing spot scans in order to achieve higher resolution measurements. If the wavelength range selected is greater than the minimum available, the Scan button is disabled, allowing the user to only perform spot scans until the wavelength range is reduced.

4 Click the **Spot Scan** button in the **System Control** area. Click the **Spot Scan** button to start continuous scanning. This button will turn gray during continuous scanning. The resulting **Spot Scan** will be displayed in **Trace A** in the upper graph area. If continuous scanning was selected then the **Continuous Spot Scans** will appear in the lower graph.

Frequency Domain Windowing

The OBR software provides the option to apply a Hanning window to the frequency domain data for new scans. The window is only applied to new data as it is scanned and will not affect data already loaded into other traces. Saved binary files retain this windowing.

The frequency domain window setting is toggled on (checked) and off by using the menu selection **Options > Display Options > Apply Frequency Domain Window**.

The **Measurement Details** dialog box (Figure 5-2 on page 61) shows whether or not the **Frequency Domain Window** was applied to the data.

4

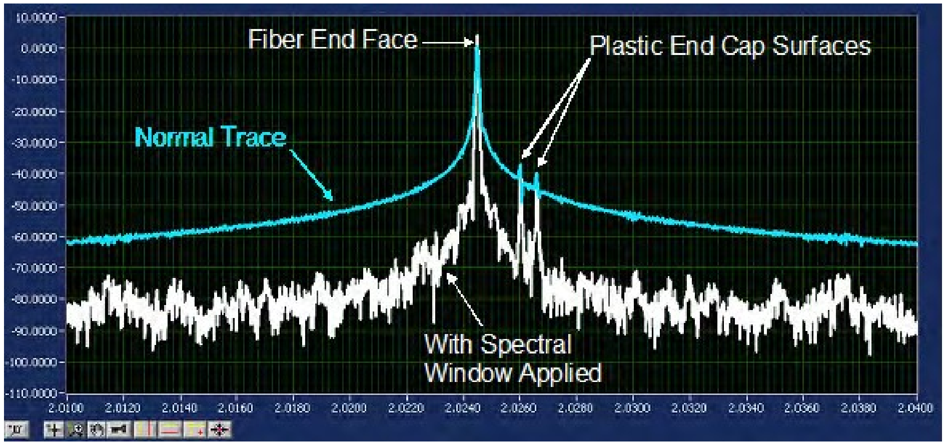


*Figure 4-7. Amplitude of a flat end face reflector. The **Blue** trace shows the data **without the Frequency Domain Window** applied. The **White** trace shows that **applying the Frequency Domain Window** makes the peak details more evident.*

Distributed Sensing Measurements

If the user purchases this option, s/he can measure five distributed sensing parameters: spectral shift, spectral shift quality, temperature change, strain, and temporal shift. The user begins by performing a measurement at ambient state and storing this measurement in **Trace E**, the **Shift Reference**. After a strain or temperature perturbation is applied to some portion of the fiber under test (FUT), a second measurement is taken and compared to the reference measurement. For the theoretical background on these measurements, see “Optional Distributed Sensing Parameters” on page 187.

Important

When calculating **Sensing** curves, the **Sensing Range** used must begin in a region of zero temperature or strain difference between the reference and measurement files. This is necessary to align the measurement files for spectral and temporal correlations. Similarly, **Spot Scans** must begin in a region of zero temperature or strain difference between the reference and measurement files.

If the calculation area (i.e. integration width or spot scan region) does not begin in a region of zero strain or temperature difference, the correlation algorithms will fail. This can be witnessed by discontinuous sensing data and low (> 0.15) spectral shift quality.

Temperature Change and Strain Coefficients

The **Temperature Change** and **Strain** curves are generated by converting the **Spectral Shift** curve from values in GHz to degrees C or microstrain. This conversion is done using a 4th order polynomial fit. The user may specify the coefficients for this conversion by selecting **Options** > **Temperature and Strain Coefficients**, which calls up the dialog box below.

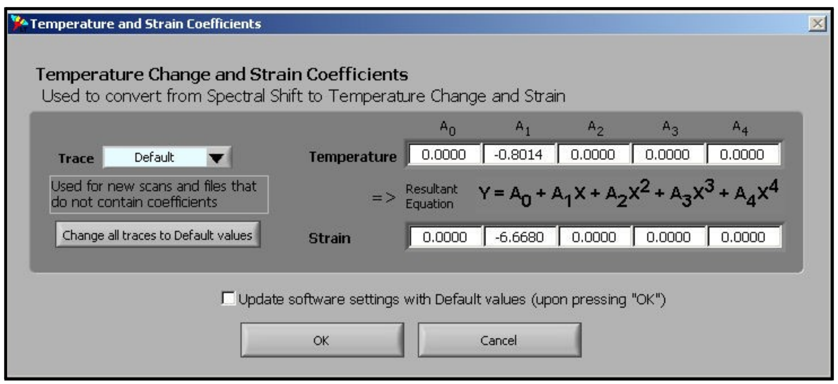


*Figure 4-8. Select **Options > Temperature and Strain Coefficients** to call up this dialog box. The user-adjustable coefficients control how the software converts from **Spectral Shift** to **Temperature Change** or **Strain**.*

This window allows the user to specify the coefficients used for each individual trace, and the default coefficients to be used for new scans. When the window is first opened, it shows the default coefficients. These coefficients will be used whenever a new scan is taken.

The coefficients for each individual trace may be viewed or modified by using the **Trace** pull-down menu. A trace may have different coefficients from the default values. For example, if a file is loaded into **Trace B**, the coefficients for **Trace B** will be those stored in the binary file, not the default coefficients currently being used for new scans. Likewise, if the user changes the default coefficients after scanning data into **Trace A**, the **Trace A** coefficients will still be set to the values used when originally taking the scan.

The default coefficients have been set for standard SMF 28 fiber. To calibrate these coefficients to another type of fiber, first measure the **Frequency Shift** of that fiber. Use external sensors to measure the actual scaling factors of your fiber. Then enter the correct coefficients under **Options > Temperature and Strain Coefficients**.

The **Change all traces to Default values** button changes the coefficients for all of the traces to match the default values. This button is only visible when viewing the default coefficients.

Important

If a trace contains data loaded from a file, changing the coefficients for that trace does not change the file that was loaded. The new coefficients will be used to generate the **Temperature Change** and **Strain** curves during the current run of the software, but the coefficients stored in the file will remain the same *unless the user resaves the binary file*.

The default coefficients are stored in the OBR software configuration file. If the **Update software settings** checkbox is checked, then pressing the **OK** button will save the new coefficients to the configuration file, as well as updating the values currently being used. (The default coefficients are also saved when the user selects **File > Save Software Options** from the main menu.)

If the user presses the **Cancel** button, no changes are made to any of the coefficients, either the defaults or those for the individual traces.

Changing the coefficients for a trace does not cause the lower graph curves to be immediately updated. If either the **Temperature Change** or **Strain** curve is being displayed in the lower graph, the user should press the recalculate button to recompute the curve with the new coefficients. If any other curves are displayed, it is not necessary to recalculate, as the coefficient values do not affect other curve types.

Distributed Sensing Technique

1 Turn **Options > Sensing Enabled** on, as indicated by a check mark by that menu item.

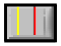
2 By default, the OBR performs **Sensing** measurements at the fastest scan rate available for your instrument. To achieve this, the instrument is automatically switched to **Fast Scan Mode**. (See “Fast Scan Mode” on page 44.) If a slower scan rate is desired, select **Options > Fast Scanning > Set Fast Scan Rate**. In the dialog box that appears, set the scanning rate.

   Note that you do not need to select **Options > Fast Scanning > Fast Scanning Enabled**, because it is automatically enabled when **Sensing** is enabled. Upon turning off **Options > Sensing Enabled**, the instrument returns to the **Scan Rate** that was in use before enabling **Sensing**.

3 Perform a measurement on the FUT under ambient conditions, *without applied strain or temperature perturbation*. (See “To perform a single-scan measurement” on page 41.) Move this data from **Trace A** to the **Shift Reference**, which is the last **Trace** in the list. For example, if five traces are available, click the button labeled **A->E** under the **Operations** column of the **Display Options** area.

   Alternatively, the user may load such data from the hard drive directly into **Trace** labeled **Shift Reference** as follows. Select **File > Load Reference File**. In the dialog box that appears, choose the desired **Trace** location, then browse for the file and click **Open**.

4 Apply strain or a temperature perturbation to some point along the length of the FUT. Scan the fiber in the perturbed state. This data automatically loads into **Trace A**.

5 Turn on the vertical cursors in the upper graph by clicking .

6 Adjust the cursor locations in the *upper graph* as desired by selecting the cross-hair  tool, then clicking and dragging a cursor.

7 If **Options > Cursors > Show Sensing Area** is on (checked), the regions of the graph around the vertical cursors are highlighted. The **Sensing**

Area is the only segment that will appear in the lower graph. The user may change the width of the highlighted area (and lower graph X-axis) by entering a new **Sensing Range** in the **Data Processing** area.

8 Make sure that the **Sensing Area** begins in a region of zero temperature or strain difference between the **Reference** and measurement files. (See Note under “Distributed Sensing Measurements” on page 48.)

9 If **Options** > **Display Options** > **Auto-Update Lower Graph** is off (unchecked), click the blue recalculate button in the upper left of the *lower graph*.

By default, the lower graph will be based on the data integrated by the left (yellow) cursor from the upper graph, as indicated by the yellow button to the left of the recalculate button. To see the data from the right (orange) cursor, click to the right of the recalculate button, then click the recalculate button again.

10 Adjust the **Gauge Length** (in the **Data Processing** area of the main screen) as needed, according to the discussion below. The **Gauge Length** (see below) should always be smaller than the **Sensing Range**.

11 Use the right pull-down menu to select **Frequency** or **Time Domain**, and the center pull-down menu to select the parameter displayed in the lower graph.

Gauge Length

The Rayleigh scatter profiles from the two data sets are compared in increments of fiber length Δz, as defined by the **Gauge Length** setting in the **Data Processing** area. The **Gauge Length** setting (in the **Data Processing** area) defines the width of the data block that will be used to cross correlate temporal shift and spectral shift. Thus the **Gauge Length** affects the spectral resolution and the signal-to-noise ratio of the measurement. There is, therefore, a relationship between the spectral resolution of the measurement and its accuracy in measuring the change in strain or temperature. Generally, the longer the segment used, the lower the shift measurement noise, meaning better temperature or strain accuracy and resolution.

However, if the temporal or spectral shift varies appreciably over the **Gauge Length** width, the cross correlation peak may become spread out and difficult to detect, resulting in high noise levels. Thus in fiber sections where there is a strong temperature or strain gradient, reducing the **Gauge Length** to a lower value may produce a more stable result.

Note

The **Spatial Resolution** filter (in the **Data Processing** area) does not apply to distributed sensing measurements. Instead, spatial resolution for distributed sensing measurements is controlled by the **Gauge Length** setting in the **Data Processing** area. To achieve the accuracies listed in the Specifications Sheet shipped with your instrument, set the **Gauge Length** to 2 cm.

Distributed Sensing Examples

*Figure 4-9. Control panel settings for a spectral shift measurement. Note that the **Shift Reference** is loaded (as indicated by the blue **Details** button for **Trace E**) but not displayed (the **Active Traces** check box is unchecked for **Trace E**).*

The temporal or spectral shifts are calculated for the area defined by the upper graph vertical cursor location and the **Sensing Range** setting in the **Data Processing** area. In Figure 4-9 above, the **Sensing Range** is set to 0.1 m, with the vertical cursor at 3.3 m; thus the lower graph shows the data from 3.25 to 3.35 m. The data shows a spectral shift of approximately 5 GHz, measured with a 1 cm **Gauge Length**. (For further discussion, see “Gauge Length” on page 52.)

To quantify the local spectral shifts due to a change in temperature or strain, the complex data sets are Fourier transformed back into the frequency domain. A vector sum of these two spectra is then calculated to generate a polarization-independent spectrum associated with each fiber segment.

An example of a small spectral shift for the data displayed in Figure 4-9 is shown in Figure 4-10 below. In this case the lower graph selection options were changed from **Time Domain** to **Frequency Domain** and from **Spectral Shift** to **Return Loss**, and the frequency axis scale was reduced to show close-up detail of the spectral signatures of **Traces A** (blue) and **E** (purple). **Trace A** appears as a similar version of **Trace E**, shifted in frequency by +5 GHz, consistent with the spectral shift result in Figure 4-9.

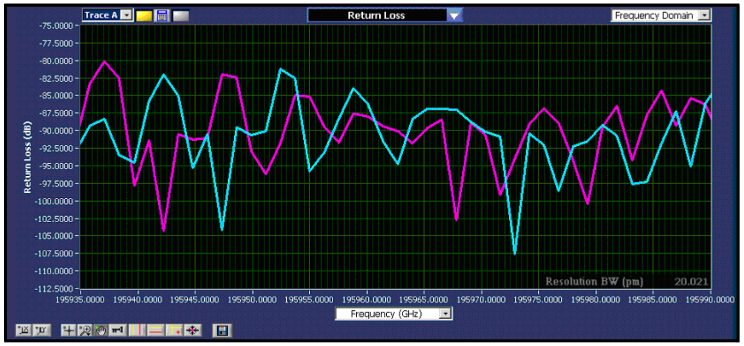
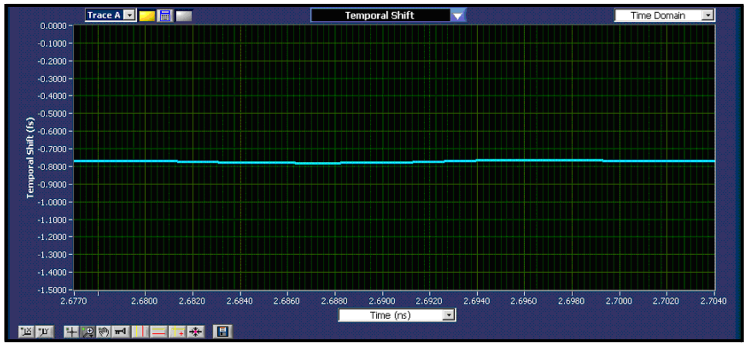


*Figure 4-10. Close-up of a part of the spectrum for the yellow cursor in Figure 4-9. **Trace A** (blue) and **Trace E** (purple—the **Shift Reference**) exhibit similar features, but **Trace A** is shifted roughly 5 GHz to the right of **Trace E**.*

Figures 4-11 and 4-12 show temporal shift results for a different section of the FUT data shown in the upper window of Figure 4-9. The temporal shift displayed in Figure 4-11 agrees well with the observed shift in the temporal return loss amplitude patterns for **Traces A** and **E** shown in Figure 4-12.

4



4

Figure 4-11. Results of the cross correlation calculation for a section of the FUT in Figure 4-9, which shows roughly -0.8 fs ***Temporal Shift*** *between perturbed and the* ***Shift Reference****,* ***Trace E****.*
Trace A

Figure 4-12. The reflection ***Amplitude*** *for the same temporal range as in Figure 4-11 for* ***Trace A*** *(blue) is shifted by roughly -0.8 fs to the left of the* ***Shift Reference, Trace E*** *(purple).*

The spectral shift and temporal shift for the same segment of fiber over which a constant strain is applied are shown in Figures 4-13 and 4-15. These plots illustrate that the temporal shift is a scaled integral of the spectral shift: where the spectral shift is zero, the temporal shift curve is flat, and where the spectral shift is large and steady, the temporal shift curve shows a steady upward slope.

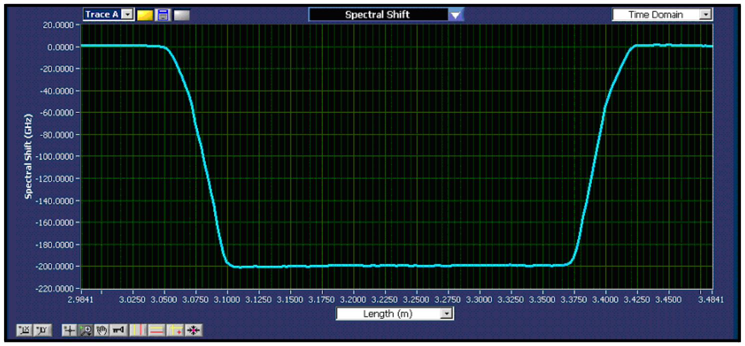


Figure 4-13. ***Spectral Shift*** *result for a constant strain applied to a 32 mm length of fiber.*

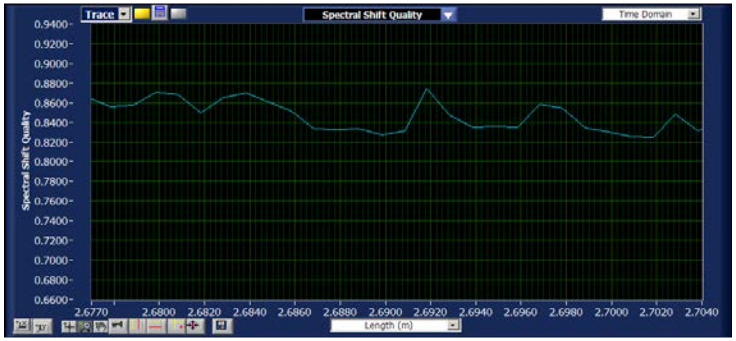


Figure 4-14. Calculated ***Spectral Shift Quality*** *result for the same source data and same length range as in Figure 4-9.*

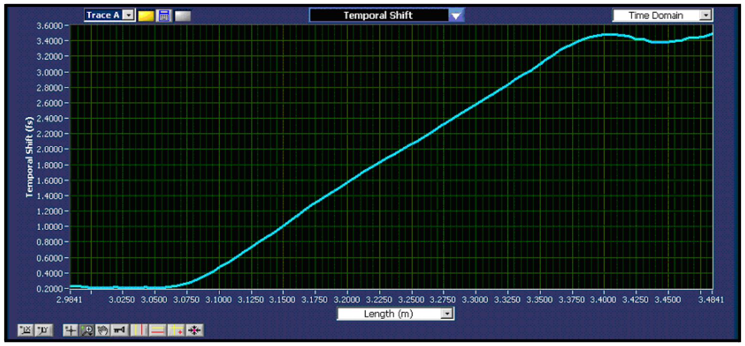


*Figure 4-15. **Temporal shift** results for the same source data and same length range as in Figure 4-13.*

4

Chapter 5

Data Processing and Display

Once a measurement has been performed, the OBR control software provides many tools for manipulating and displaying measured data. Data stored in the local memory of the software can be used to display any of the parameters described under “Standard Parameter Calculations” on page 179. Data may be saved to a file in either a binary or spreadsheet format. Also included are powerful zoom and cursor features to enhance the usefulness of the display.

5

Displaying Multiple Traces

The OBR control software allows the user to store five data sets in active memory, or two sets in desktop analysis mode (*i.e.* when the OBR is off or disconnected). These memory locations are denoted **Traces A** through **E**. The most recent measurement is always stored in **Trace A**.

Important

New scans are automatically loaded into **Trace A**, overwriting any data there. To avoid losing data, see “Moving Data in Local Memory” below, or “Saving and Loading Data Files” on page 62.

Moving Data in Local Memory

Data **Trace A** may be moved to **Trace B** by clicking the button labeled **A->B** under the **Operations** column of the **Display Options** area shown in Figure 5-1. Data may also be moved in a similar manner to **Traces C**, **D** or **E**. However, only two traces are available when operating in desktop analysis mode (*i.e.* when the OBR is off or disconnected). The original data in **Trace A** remains in **A** until new data is scanned by the instrument or loaded from the hard drive.

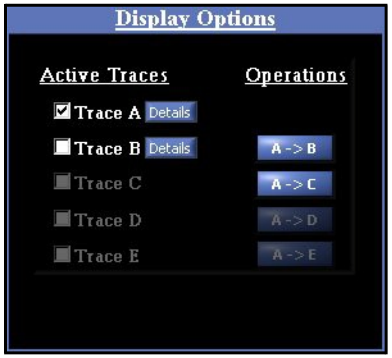


*Figure 5-1. The **Display Options** area in the main OBR software window. In the example, data has been loaded into **Traces A** and **B**, but only **Trace A** is being displayed, as indicated by the check boxes.*

5

Displaying Stored Data

The control software can display any combination of **Traces A** through **E** simultaneously in the graph windows if the OBR is on and connected. By default the data in **Trace A** is plotted as a blue curve, **Trace B** is red, **Trace C** green, **Trace D** yellow, and **Trace E** pink. In the example in Figure 5-1 above:

1. **Trace A** contains data, as indicated by the white name and checkbox and the blue **Details** buttons. **Trace A** is being graphed, as indicated by the filled-in checkbox. To clear this graph, click to clear the checkbox by **Trace A**.
2. **Trace B** also contains data but is not being graphed. Clicking in the second checkbox adds **Trace B** to the graph window.
3. **Traces C** has no data in it, as indicated by the grayed name and lack of a **Details** button. To overlay another plot, the user could move data into this trace using the **A->C Operations** button or by loading data from the hard drive. (See “Saving and Loading Data Files” on page 62.)
4. If the headings for **Traces C** through **E** are not visible at all in the **Data Management** area, this indicates that the software is operating in “Desktop Analysis” mode. To make these traces available, the user would have to connect and turn on the OBR.

5 When data is loaded into local memory (by selecting **File > Load Data File** or by scanning) or moved within local memory (by clicking an **Operations** button), it is automatically displayed in the upper graph window.

Trace Details

Clicking a **Details** button in the **Data Management** area calls up the **Measurement Details** window shown in Figure 5-2. This window lists the type of measurement, the scan date, the reference date, the **Gain** setting, and whether the **Frequency Domain Window** was applied to the data. If the file has been loaded from the hard drive rather than scanned into **Trace A**, the file path will be listed. The user may type in a one-line **Device Descriptor.** The user may also use this dialog box to change the group index of one trace at a time. The **Save and Close** button is only available after new data has been entered into the **Device Descriptor** field or the **Group Index** field *and* after moving the cursor to a new location in the **Measurement Details** window.

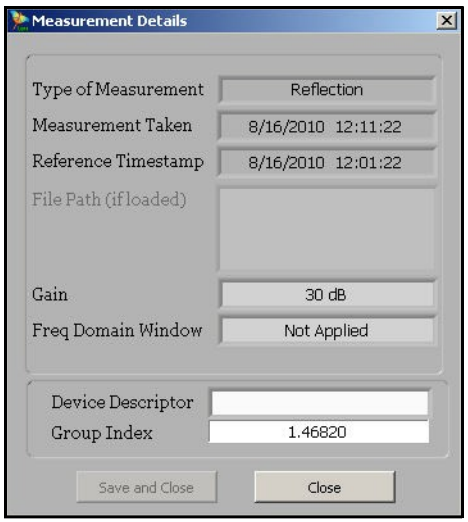


*Figure 5-2. **Measurement Details** window.*

The user can also use the **Group Index** field in the lower right corner of the upper graph when the X-axis displays length, but this effects *all* of the data loaded into **Traces A** through **E**. (See “Adjusting Group Index” on page 75.)

When the upper graph X-axis displays length, the **Group Index** field shown below appears in the lower right corner. The user may enter the index appropriate for the device under test.

Saving and Loading Data Files

The OBR control software provides two options for saving data files. The first file type (.obr) is a binary data format that completely captures the measured data and stores it in a format that can be loaded back into the control software at a later time for further manipulation. The user may also save a smaller portion of the measured data, highlighted by one vertical cursor in the upper graph; these file names end in "_Segment.obr." Binary segments may also be reloaded into the OBR software.

The second file type is a text file in a tab-delimited spreadsheet format. Text files contain the data displayed in the upper (_Upper.txt) or lower (_Lower.txt) graphs at the time of saving. Data saved in the spreadsheet format cannot be loaded back into the control software.

It is highly recommended that the binary data format be chosen over the spreadsheet format for data archives. The binary format stores all measurement information, whereas the spreadsheet format stores only a subset of the measured information. Furthermore, a spreadsheet file can always be generated from a binary file at a later date, but a binary file cannot be generated from a spreadsheet file. Finally, other data analysis software packages available from Luna Technologies accept only the binary data format produced by the OBR control software.

Saving Data

Depending on which options are set in the **File** > **Select File Options** dialog box (Figure 5-3), up to four files may also be saved each time **File** > **Save Data Files** is selected. As an example, if the user saves the data as *Your_Filename*, the four files would be:

1. *Your_Filename.obr* is the complete binary file, which can be reloaded into the OBR software.
2. *Your_Filename_Segment.obr* is a subset of the data displayed in the upper graph. This subset is the region integrated by the vertical cursor in the upper graph and displayed in the lower graph. These files may also be reloaded into the OBR software.

3 *Your_Filename_Upper.txt* is a spreadsheet file of all of the upper graph parameters selected in the **File > Select File Options** dialog box.

4 *Your_Filename_Lower.txt* is a spreadsheet file of all of the lower graph parameters selected in the **File > Select File Options** dialog box.

Important

When **File > Save Data Files** is selected, the OBR software will overwrite any files with the filename specified, *without warning the user*.

Make sure to update the lower graph, following instructions on page 67, as the segment saved will be the one displayed.

Spreadsheet files cannot be reloaded into the OBR software. Therefore, a warning message will be displayed the first time the user saves data with the **Save Full Measurement File** box unchecked. This warning will not be displayed again until the user restarts the software.

5

To specify options for saving data

1 Select **File** > **Select File Options**

The **Select File Options** dialog box shown below opens.

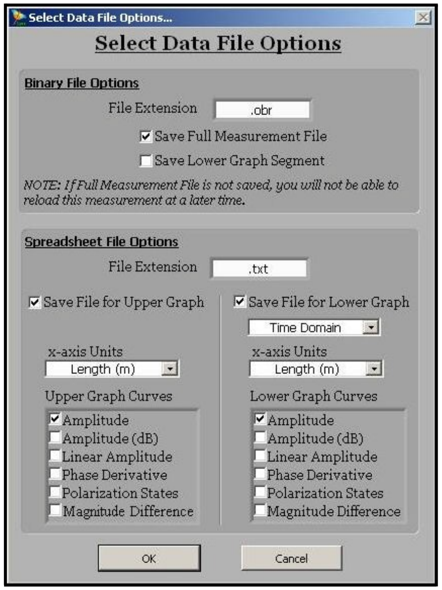


*Figure 5-3. **Select Data File Options** dialog box. WIth the setting shown, the full binary file and the lower graph spreadsheet file for two parameters will be saved.*

2 A binary file of the complete data will only be saved if the **Save Full Measurement File** box is checked. If **Save Lower Graph Segment** is checked, the software will also save a binary file of the data displayed in the lower graph. All of the data in that segment will be saved, not just the parameter displayed. This allows the user to save and manipulate smaller binary files. These **Lower Graph Segment** binary files may also be reloaded into the software.

3 To set the software to save spreadsheet text files whenever **File** > **Save Data Files** is selected, check the appropriate box(es) under **Spreadsheet File Options**.

Important

Spreadsheet files, of type ".txt," cannot be reloaded into the OBR software.

4 Click **OK.**

The control software saves the selected options.

To save data

1 Update the lower graph as desired, following instructions on page 67.

2 Select **File** > **Save Data Files**.

A dialog box appears.

3 Select the file destination and enter a file name. The file extension(s) will be added automatically according to the configuration set using **File** > **Select File Options**, as described above.

4 Click **Save**.

Loading Saved Data

Only data saved in the binary format (.obr) can be loaded into the control software.

To load a saved data file

1 Select **File** > **Load Data File** from the pull-down menu.

2 In the dialog box that appears, select the target memory location (**Trace A-E**) from the list. The LED for the selected **Trace** will be bright green. Hit enter or click **Continue**.

3 In the next dialog box that appears, choose the desired file and click **Open**.

The loaded data will appear in the upper graph area. To control the contents of the lower graph, see "Updating Lower Graph" on page 67.

Spreadsheet File Data

The header of a spreadsheet file gives the following information:

- Date and time data was acquired
- Reference date and time
- Device descriptor (The user may enter a descriptor after clicking the **Details** button in the **Data Management** area.)
- Measurement Type
- Group index
- Gain
- Spatial resolution
- Frequency Domain Window status
- Number of data points
- Decimation

Only the units and parameters selected (checked) in the **File > Select File Options** dialog box will be contained in a spreadsheet file. The parameter name and the units are given at the top of each spreadsheet column.

Displaying Two Parameters in Lower Graph

The user may display two parameters in the lower graph area by clicking on **Options > Lower Graph > Two Plots**. A check mark by this sub-menu item means **Two Plots** have been enabled. The lower graph will then display two parameter selection pull-down menus in the **Title Bar**, as shown in Figure 5-4 below. Note that there are also two X-axes, one for each parameter. Only the data in **Trace A** may be displayed in two plots.

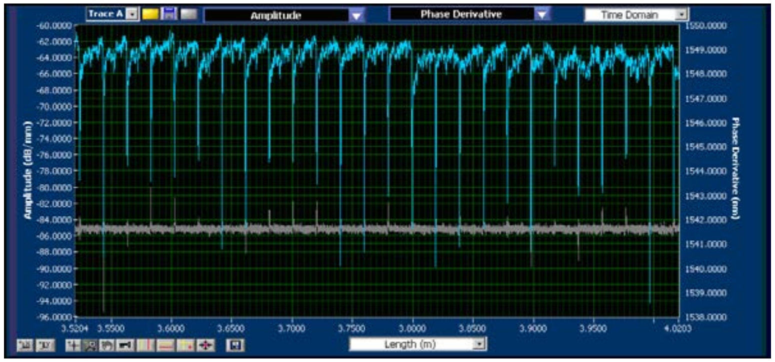


*Figure 5-4. The lower graph area can display two parameters at a time if **Options > Lower Graph > Two Plots** is enabled (checked).*

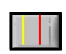
Manipulating Plots

The OBR control software gives the user great control over the content and appearance of the data plots. This section covers parameter selection, zooming, scaling, and cursors.

Updating Lower Graph

The data in the upper graph automatically updates when data is scanned (into **Trace A**), moved, or loaded from memory. However, the lower graph will not update automatically unless **Options** > **Display Options** > **Auto-Update Lower Graph** is checked. As mentioned earlier, this is often left off (unchecked) to speed up scanning time. The lower graph will automatically update after a **Continuous Spot Scan**, provided the yellow vertical cursor is located within the **Spot Scan** region. (See “Spot Scan Mode” on page 44.)

To update the lower graph

1 Turn on the vertical cursors in the upper graph by clicking .

2 By default, the vertical cursors are attached to **Trace A**. To attach the cursors to another trace, select a different trace from the pull-down menu in the **Title Bar** 

.

3 Adjust the cursor locations in the *upper graph* as desired by selecting the cross-hair  tool, then clicking and dragging a cursor.

4 If **Options > Cursors > Show Integration Area** is on (checked), the regions of the graph around the vertical cursors are highlighted. This highlighted segment is the only data that will appear in the lower graph. Lower graphs of all traces will be based on this same segment of the X-axis.

The user may change the width of the highlighted area (and lower graph X-axis) by entering a new **Integration Width** in the **Data Processing** area of the main window.

Note: When **Options** > **Sensing Enabled** is on or checked (if purchased), the fields in the **Data Processing** area change. To control the width of the highlighted area in **Sensing Mode**, change the **Sensing Range** in the **Data Processing** area. The menu item for activating these highlighted areas around the vertical cursors becomes **Options** > **Cursors** > **Show Sensing Area**.

5 Click the blue recalculate button  in the upper left of the upper graph.

By default, the lower graph will be based on the data highlighted around the left (yellow) cursor from the upper graph, as indicated by the yellow button to the left of the recalculate button.

6 To see the data from the right (orange) cursor, click to the right of the recalculate button; the button will turn from gray to orange: . Then hit the recalculate button again.

Note

The recalculate button  only appears in the top left of the upper graph when the vertical cursors are on in the upper graph.

7 To change the parameter displayed in the lower graph, follow the next set of instructions.

Parameter Selection

The user can control the content of the two graphs in the main window from a list of parameters in the **Title Bars**. By default, the upper graph displays amplitude (in dB/mm), but it can also display linear amplitude, polarization states, or amplitude (dB). The lower graph can also display these same parameters.

To change the content of a graph window

1 Click on the **Title Bar** of the graph. A drop-down list of the available plot parameters appears.

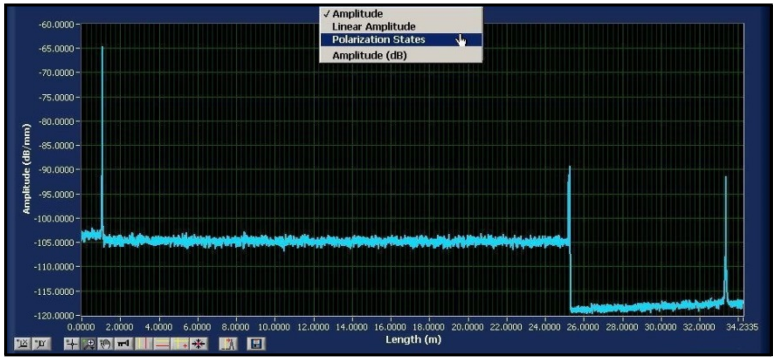


*Figure 5-5. Upper graph window showing the **Title Bar** pulled down for parameter selection.*

2 Click on the desired parameter from the list.

The content of the graph changes, as do the title and the axis labels (if necessary).

Scaling Plot Axes

The OBR control software provides several ways for adjusting the scaling of the graph windows.

Autoscaling

Autoscaling refers to the automatic adjustment of plot axes so that all of the data fits in the graph window.

By default, the graph windows will autoscale the Y-axis when new data is scanned or loaded from memory. To toggle autoscaling on and off for either graph area, select **Options > Display Options > Autoscale Y Axes (Both Graphs)** or **Autoscale X Axis (Upper** or **Lower Graph)**. A check mark next to these selections indicates that autoscaling is turned on. Note that the lower graph X-axis scale is based on the highlighted section of a vertical cursor in the upper graph.

At other times, the user may rescale each plot axis independently by using the autoscale buttons for the X-axis  and the Y-axis , located in the lower left corner of each graph window.

Manual scaling

The plot axes may be scaled manually by double-clicking on either the lowest or highest value labeled on the axis and typing in a new value. To accept the new value, press enter or click anywhere in the screen.

Note that by using this method it is possible to flip the graph so that increasing values on the X-axis run from right to left, and increasing values on the Y-axis run from top to bottom. Typically this is to be avoided, so be sure to enter appropriate values.

Using zoom tools

There are six available zoom tools, which are accessible by clicking the **zoom menu button**  located in the lower left corner of each graph window.

When this button is clicked, a pop-up window containing the six zoom tools opens:

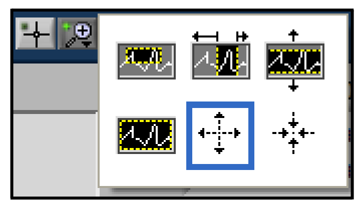
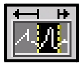


Figure 5-6. Zoom tools pop-up menu. A blue border surrounds the selected tool.

The zoom window tool: 

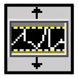
This tool allows the user to zoom in on a rectangular region of the graph window.

To use this tool, first select it from the zoom menu button. Then click in the graph window and hold the mouse button to define one corner of the rectangular region. Then drag the mouse cursor and note that a dotted box appears with corners defined by the original click position and the current mouse cursor position. Drag the box around the desired region of the graph window and release the mouse button. Both the X- and Y-axis scales adjust so that the selected region fills the entire graph window.

The X-axis zoom tool: 

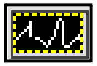
This tool allows the user to zoom in on a region of the X-axis only, without adjusting the Y-axis scale. This is the default tool active in each graph when the software is opened.

To use this tool, first select it from the zoom menu button. Then click in the graph window and hold the mouse button to define one edge of the desired X-axis region. Drag the mouse cursor to the other edge of the desired region and note that a fixed vertical dotted line appears where the original click occurred, and another follows the mouse cursor. When the cursor is positioned at the other edge of the desired region, release the mouse button. The X-axis scale adjusts to show only the selected region.

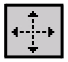
The Y-axis zoom tool: 

This tool allows the user to zoom in on a region of the Y-axis only, without adjusting the X-axis scale.

To use this tool, first select it from the zoom menu button. Then click in the graph window and hold the mouse button to define one edge of the desired Y-axis region. Drag the mouse cursor to the other edge of the desired region, and note that a fixed horizontal dotted line appears where the original click occurred, and another follows the mouse cursor. When the cursor is positioned at the other edge of the desired region, release the mouse button. The Y-axis scale adjusts to show only the selected region.

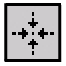
The return to full zoom tool: 

Selecting this button from the zoom menu returns the graph to the full scale of all data.

The zoom in tool: 

This tool allows the user to zoom in (magnify) the graph from the point where the cursor is clicked.

To use this tool, first select it from the zoom menu button. Then click once to magnify once; or click, hold and release to magnify several times at the cursor location.

The zoom out tool: 

This tool allows the user to zoom out from the point where the cursor is clicked.

To use this tool, first select it from the zoom menu button. Then click once to zoom out once; or click, hold and release to zoom out several times at the cursor location.

Using Cursors, Legends and Other Buttons

Cursors

The OBR software offers three types of cursors. By default, vertical cursors and twin locked cursors appear at 10% and 90% of the X-axis range. Horizontal cursors appear at 10% and 90% of the Y-axis range. To move the cursors, select the cross-hair , then click, drag, and release the cursor.

The cursors are attached to **Trace A** by default. To attach cursors to a different trace, select that trace from the Trace A pull-down menu.

5

When any of the cursors are on, a legend appears in the upper right corner giving the exact location of the cursors in the units currently selected. The legend also indicates the distance between the two cursors (dX for vertical cursors, dY for horizontal cursors, and dX and dY for twin locked cursors).

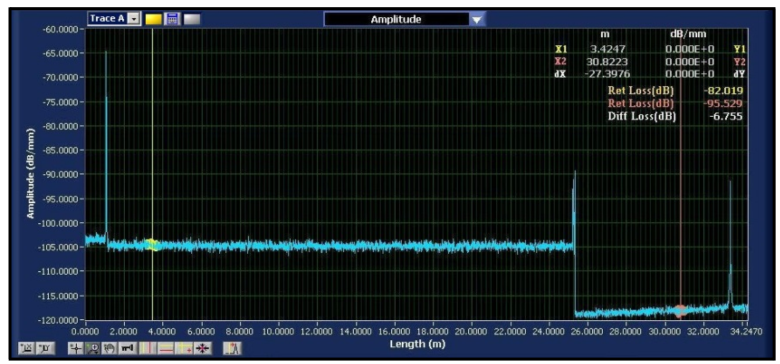


Figure 5-7. Upper graph showing the amplitude data with vertical cursors appearing at the default location. The legend at the upper right gives the precise location of the cursors and the distance between them (dX in this case). The legend also displays the return loss at each cursor and the differential loss between the two cursors. Note that the data points integrated to calculate differential loss are highlighted in contrasting colors

Vertical cursors:

Clicking this button toggles two vertical cursors on or off. Note that when these cursors are on, the data points integrated to calculate return loss and differential loss are highlighted in contrasting colors, and the results are displayed in the upper right legend. This highlighted region may be turned off by unchecking **Options > Cursors > Show Integration Area**. [Or, in optional **Sensing Mode** (page 48), **Options > Cursors > Show Sensing Area**.] This highlighted or integrated region determines the X-axis of the lower graph.

The number of points integrated may be increased (or decreased) by entering a larger (or smaller) number in the **Integration Width** field in the **Data Processing** area of the main window. [In **Sensing Mode**, the width of the integration area is controlled by the **Sensing Range** field in the **Data Processing** area.]

For an explanation of how differential loss is calculated, see “Return Loss and Differential Loss” on page 178.

As mentioned above, select the cross-hair tool to move cursors.

Horizontal cursors:

Clicking this button toggles two horizontal cursors on or off.

Twin locked cursors:

Clicking this button toggles twin locked cursors on and off. Regardless of where these cursors are dragged, they will intersect the graph at a data point on the first trace displayed. So to use twin locked cursors on **Trace C**, for example, deselect **Traces A** and **B** in the checkboxes in the **Data Management** area.

Bring cursors to center:

Clicking this button brings the active cursors into the viewed portion of the graph.

Move cursors to peak:

Clicking this button moves the two vertical cursors to the peaks of the regions highlighted by each cursor. Simply click on this button when the vertical cursors are on.

5

Spot Scan Cursor:

Clicking this button turns on the spot scan cursor.

Select the cross-hair tool to move the spot scan cursor to a region of the data where you desire a spot scan. See “Spot Scan Mode” on page 44 for more details.

Spot Scan Cursor Unlocked or Locked Toggle Button:

Clicking the first button (showing the unlocked icon) locks the spot scan cursor to the active vertical cursor. The button icon with then change to a closed lock:

Clicking this button again will unlock the spot scan cursor from the active cursor. The icon changes to display the current state of the cursors.

See “To perform continuous spot-scan measurements” on page 46 for more details.

Save graph as image file:

Clicking this button in the upper (or lower) graph area prompts the user to save the current upper (or lower) graph as a .jpg image file.

The pan tool:

This tool lets the user pan around the data in a graph window. To use this tool, first select it from the button menu, then click on the graph and drag the cursor.

The recalculate buttons:

See “Updating Lower Graph” on page 67

Legend

A plot legend can be displayed by clicking the button in the graph window.

Changing graph style and color

The user may change the color or line style of an individual graph by first turning on the legend. Next, click inside the legend to call up a menu which allows the user to select line color, style, and width.

Adjusting Group Index

When the upper graph X-axis displays length, the **Group Index** field shown below appears in the lower right corner. The user may enter the index appropriate for the device under test.

*Figure 5-8. The **Group Index** field, which appears to the lower right of the upper graph.*

Important

Changing the group index in the box shown above changes the group index for *all* the data loaded into memory, **Traces A** through **E**. In order to change the group index of only one trace, click the **Details** button of that trace and change the group index in the details dialog box. (see “Trace Details” on page 61)

The group index scales the X-axis length values according to

$$z = \frac{c}{2n_g}t \quad ,$$

where z is the spatial dimension (X-axis) of the device under test, c is the speed of light in a vacuum, t is time, and n_g is the group index of refraction of the device under test.

Data Decimation

Selecting **Options** > **Data Decimation (Upper Graph)** > **Specify Level** calls up the dialog box shown below (Figure 5-9). Here the user can select the number of data points displayed in the upper graph, up to 524,288 points.

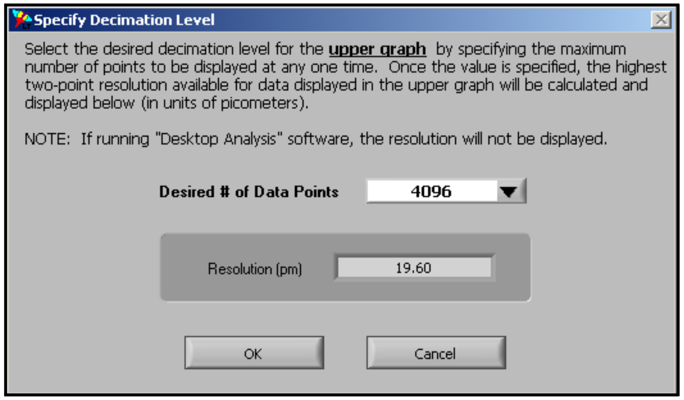


*Figure 5-9. The **Specify Decimation Level** dialog box allows the user to set the number of data points displayed.*

Decimation makes the graphs much less "noisy" and quicker to display. Note that files saved in the binary (.obr) format contain the raw data, undecimated. Text files (.txt) may be reduced in size by selecting a smaller number of points to display before saving. The upper section of a text file notes the data decimation factor.

Adjusting Spatial Resolution

The user may change the **Spatial Resolution** value in the **Data Processing** are of the main screen. If the Spatial Resolution is set below the minimum achievable resolution, the software will coerce it to the actual minimum value and thus the data is unfiltered. Setting the control above this value will cause the data to be box-car filtered with the user-specified bin size equal to the **Spatial Resolution**. For an explanation of how this filter is calculated, see "Spatial Resolution Calculations" on page 178.

Printing Graphs

The user may print both graphs currently displayed by selecting **File > Print Datasheet**. The control software prints to any printer defined as the default Microsoft® Windows® printer. The graphs will print with the current filter and axis settings. The legends and cursors will not appear in the printout.

Chapter 6

LightPath Analysis Software Guide

LightPath Analysis (LPA) software may be purchased for use with the OBR. This software can quickly and easily verify the performance characteristics of fiber optic components, modules and cable assemblies for quality control purposes. LightPath Analysis software compares devices to tolerance values in either a “golden” **Reference Trace** or a **Parameter Configuration File**.

The user begins by adjusting the tolerance values in the **Parameter Configuration File** or in the golden **Reference Trace** for future pass/fail comparisons. Then the software can perform automated testing, comparing the device or component under test to the user-created standard.

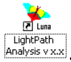
The software identifies three key features for comparison: **Peaks**, **Drops**, and **Fibers** (fiber segments). Other software features include:

- Automatic pass/fail visualization
- Return loss qualification vs. length
- Insertion loss qualification vs. length
- Automatic event mapping

Each detected **Feature** (**Peak**, **Drop**, or **Fiber**) is compared to the **Parameter Configuration File** or to the **Reference Trace**, and marked as passing or failing based on their similarity to the tolerated values. The entire trace is accepted as passing if all expected features are present and fall within the desired tolerances for return loss, insertion loss, and location.

LightPath Analysis Tutorial

This tutorial walks the user through adjusting the default **Parameter Configuration File** and creating a **Reference Trace** using Luna Technology sample files. Later sections describe how to create these files from your own devices, and how to use these standards to pass or fail test data. Many of the LPA commands and tools also exist in the OBR software and are described in Chapter 3, beginning on page 17.

If your system did not come with the LightPath Analysis software preinstalled, contact Luna Innovations Incorporated for installation files and instructions. Make sure there is no other software running, including the OBR software. Start the software from the Windows® **Start** menu, or by clicking the desktop icon . A splash screen displays the software name, version, and date until the main screen (Figure 6-1) loads.

The LightPath Analysis software comes installed with a default parameter file (*lpa_default_params.ini*) and the three example data files (*device1.obr*, *device2.obr*, and *device3.obr*) that are used in this tutorial. These files are all located in the same directory as the LightPath program file (LPA.exe). Normally, this will be the folder *C:\Documents and Settings\All Users\Application Data\Luna Technologies\LightPath Analysis v#.#*.

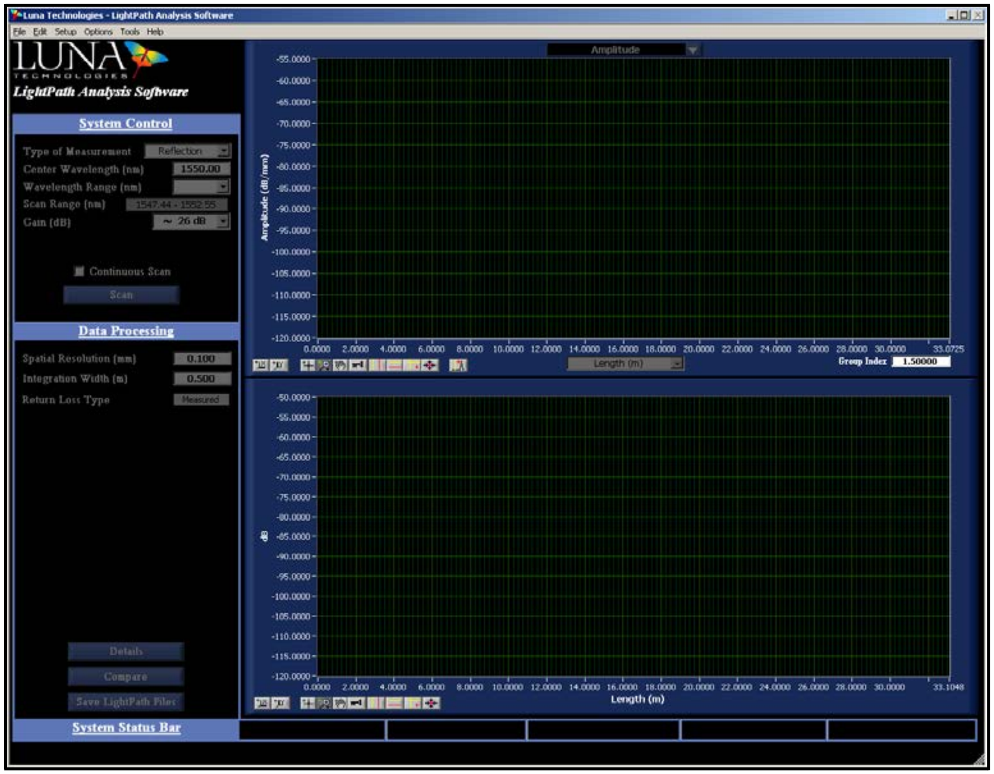


Figure 6-1. ***LightPath Analysis*** *software main screen.*

Adjusting a Parameter Configuration File

From the main menu, select **Setup > File Configuration**. The **Specify File Paths** window appears, as shown in Figure 6-2, allowing the user to set the **Reference Trace Folder**, **Parameter Configuration File**, and **Base Folder for Output Data**.

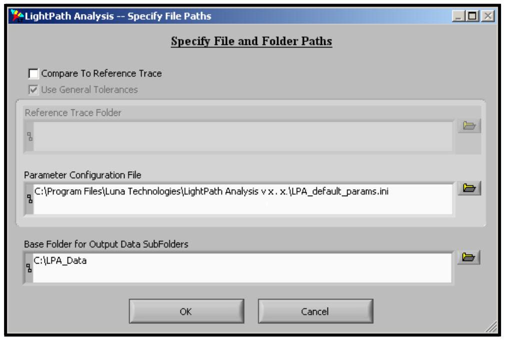


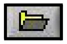
*Figure 6-2. Selecting **Setup > File Configuration** from the main window calls up the **Specify File Paths** window.*

6

New data traces can be compared either to a **Reference Trace** or to a set of default parameters held in a **Parameter Configuration File**. By default, the software is configured to use the parameter configuration file *lpa_default_params.ini*, located in the folder where the software was installed (*C:\Documents and Settings\All Users\Application Data\Luna Technologies\LightPath Analysis v#.#*).

The **Compare to Reference Trace** option is unchecked by default, (meaning the data will be compared to the **Parameter Configuration File**), and no **Reference Trace Folder** is specified.

The **Base Folder for Output Files** is set to *C:\LPA_Data*. All saved traces will be saved into subfolders located in this folder. Usually, a different **Base Folder** will be specified for each part number being tested, and the results for each individual part tested will be saved into a subfolder within that **Base Folder**. For instructions, see “Saving LightPath Files” on page 86.

In the future, you can use the browse  button to find other files and folders. But for this tutorial, press **Cancel** to retain the default settings.

Loading a File

One would normally begin setting up the LPA software by clicking **Scan** in the **System Control** area of the main screen, and then adjusting tolerance levels in this file to create a **Reference Trace**. But this tutorial will use a pre-scanned file to teach how to create a **Reference Trace**.

Select **File > Load Data File** from the menu; browse and open the file *device1.obr*, located in *C:\Documents and Settings\All Users\Application Data\Luna Technologies\LightPath Analysis v#.#*. The software will display a **Processing** dialog while generating the LightPath data. This may take several seconds.

Figure 6-3. Data from the file device1.obr *is being compared to the* ***Parameter Configuration File*** lpa_default_params.ini.

Data Display

When the loading process has completed, the software displays the **Amplitude** plot of the data in the upper graph (Figure 6-3). The lower graph shows a simplification of the trace data, broken into the **Peak**, **Drop**, and **Fiber** segments that were detected during processing.

Each feature type is represented by a different shape in the lower graph. **Fiber** segments are represented by two horizontal lines, indicating the input and output level at the front and rear end of the segment. **Peaks** and **Drops** also have horizontal lines at the input and output levels, with a vertical line at the midpoint of the segment representing the extent of the peak or drop. **Peaks** are depicted with a vertical line going from the input level to the return loss. **Drops** are depicted with a vertical line going from a floor of -115 dB to the input level.

The color of each feature indicates whether it passed or failed, compared to the values in the **Reference Trace** or **Parameter Configuration File**. **Peaks** and **Fiber** segments are shown as green (pass) or red (fail). **Drop** segments are shown as blue (pass) or purple (fail), to make them stand out visually from the peaks.

An indicator in the top right of the lower graph shows whether all segments have passed their individual tolerances 

, or if some failing segments were found in the trace 

Changing Data Processing Parameters and Tolerances

Several parameters affect the feature detection algorithm—i.e. how the software passes or fails a feature in the data. The user may adjust the parameters so that all desired features for a particular device are detected, and random noise disregarded.

In this comparison of *device1.obr* data to the default **Parameter Configuration File**, notice that the two peaks near the 2.0 m point are combined into a single feature in the lower graph. The processing parameters in the **Parameter Configuration File** can be adjusted so that these are detected as two distinct peaks.

Select **Setup > Data Processing Parameters** from the main menu to show the **Parameter Specifications** window (Figure 6-4). This displays the **Parameters** used to delineate trace segments and the **Tolerances** used to mark them as passing or failing.

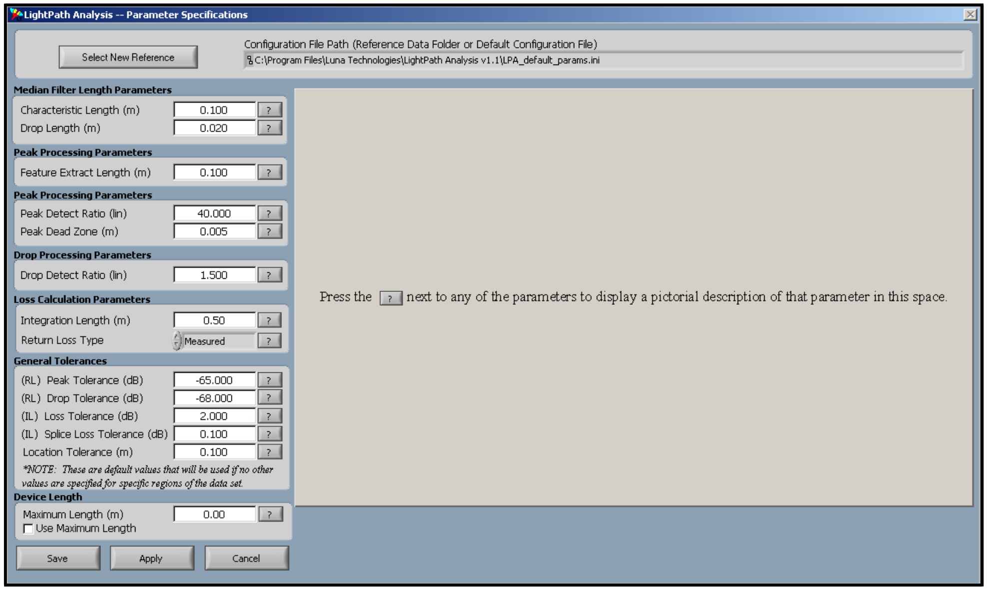


*Figure 6-4. In the **Parameter Specifications** window, the user can adjust the parameters and general tolerances used by the **Parameter Configuration File** or the **Reference Trace** to separate and to pass or fail features.*

The name of the current **Parameter Configuration File** is shown in the **Configuration File Path** box at the top of the window.

Press the question button [?] next to any parameter or tolerance setting to display a graphic explaining the how each value affects the processing. The data processing parameters are discussed in more detail under “Description of Processing Parameters and Tolerances” on page 97.

In the **Peak Processing Parameters** section on the left, change the value of the **Feature Extract Length (m)** from 0.100 to 0.050. This will cause the algorithm to generate features with smaller widths, and should cause the two peaks at 2.0 meters to generate two features instead of being combined into a single peak in the lower graph. (For further explanation, see “Feature Extract Length (m)” on page 100.)

To see how this change affected the lower graph, press the **Apply** [Apply] button at the bottom of the window. The current trace will be reprocessed with the new **Feature Extract Length**, and any new traces that are scanned or loaded will be compared to the new value. However, if a new reference or parameter configuration file is loaded, or if the software is closed, the unsaved values will be lost. This may be useful for some situations (such as this tutorial, or to briefly view the affect of a change), but has the risk of losing tolerance or processing parameter values.

Thus in general, the user would click the **Save** [Save] button in the **Parameter Specifications** window after making parameter or tolerance changes. This calls up a dialog box allowing the user to select an existing **Parameter Configuration File** or to name a new one.

Why a Feature Failed

The **Trace Comparison** window displays a detailed comparison of the detected features and the tolerance values used to evaluate their pass/fail status. To access this window, press the **Compare** button at the lower left in the main window. Note that the graph shown is the same as the lower graph in the main window.

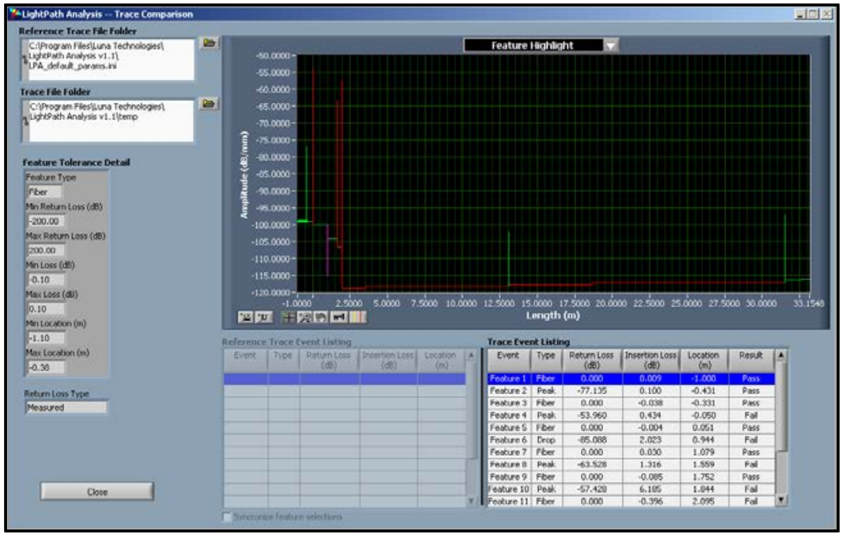


*Figure 6-5. The user may view the **Trace Comparison** window by clicking the **Compare** button in the lower left of the main window.*

The trace currently loaded in the LPA software is always being compared to a standard: either a **Parameter Configuration File** (as in this case), or a **Reference Trace**. The name of this standard for comparison—*lpa_default_params.ini*—is shown in the **Reference Trace File Folder** area at the upper left. Because the software is using a **Parameter Configuration File** for comparisons, there is no data in the **Reference Trace Event Listing** grid. (Once a **Reference Trace** is specified, this grid will contain data, as shown in Figure 6-10 on page 92.)

The **Trace File Folder** area shows the location of the trace being evaluated, in this case the currently loaded data held in a temporary directory. The features detected in the current trace are shown in the **Trace Event Listing** grid. This grid shows the **Type**, **Return Loss**, **Insertion Loss**, **Location**, and **Result** (Pass or Fail) for each feature. (Note that all fiber segments are listed with a return loss of 0 dB.)

The **Feature Tolerance Detail** area at the left displays the tolerated minimum and maximum loss and location values for the feature highlighted in the **Trace Event Listing** grid. If a feature fails any given tolerance setting, that setting will show in red in the **Feature Tolerance Detail** area. You may see the **Feature Tolerance Details** of a different feature by clicking on it in the **Trace Event Listing** grid.

The highlighted feature in the **Trace Event Listing** grid is bold in the **Feature Highlight** graph. You can also highlight a specific feature in the graph by toggling on (clicking) the vertical cursor control  and then the cross-hair  tool. Once the cursor is a cross-hair, you can click and drag over the graph to highlight each feature. The cursor will sit at the center or splice location of the selected feature.

Select several different features, using either the graph cursor or the **Trace Event Listing** grid, and view the **Feature Tolerance Detail** values to understand why each feature passed or failed.

Note the sign convention for **Loss** (insertion loss): a drop from the input level to the output level is reported as a positive value. A gain is reported as a negative value, or a “negative loss.” The fiber segments in **Features 11**, **13**, and **15** all have gains and report negative values.

For the example file *device1.obr*, the peaks in **Features 4**, **8**, and **10** have return losses greater than the maximum value of -65 dB. **Features 6** and **10** have an insertion loss greater than the maximum of 2.0 dB. The fiber segments in **Features 11** and **13** have insertion losses less than the minimum of -0.1 dB.

Press **Close** to exit the **Trace Comparison** window. Next we will show how to change the **Parameter Configuration File** so that these failed features will pass.

Editing General Tolerances

Select **Setup > Data Processing Parameters**. This returns you to the **Parameter Specifications** window (Figure 6-4). In the **General Tolerances** area, change the

(RL) Peak Tolerance (dB) value from -65 to -50. This will allow the peaks in **Features 4** and **8** to pass.

You may click **Apply** to see that these peaks are now shown in green, for passing. Then return to the Parameter Specifications window by selecting **Setup** > **Data Processing Parameters** again.

Change the **(IL) Splice Loss Tolerance (dB)** value from 0.1 to 0.6. This will allow the **Features 11** and **13** (fibers) to pass. (**Splice Loss Tolerance** determines both the maximum and minimum insertion loss values for fiber segments. **Min Loss** will now have a value of -0.6, so **Features 11** and **13** will no longer have loss values less than the minimum.)

Click **Apply** to see that these drops are now shown in green (passing) rather than red (failing). **Features 6** and **10** should now be the only failing features.

Saving LightPath Files

When you first scan or load a trace, the LightPath data files are saved to a temporary folder. The files can be saved to a permanent folder to be viewed later or to create a reference trace.

Press the **Save LightPath Files** button—near the bottom left of the main window—to save the current trace's data. The **Enter Device Descriptor** dialog appears (Figure 6-6), allowing the user to enter a short description of the device. This name is used to create a subdirectory in the folder that was specified as the **Base Folder for Output Files** in the **Specify File Paths** window (Figure 6-2 on page 80).

Enter the name “golden” to save the data to the folder *C:\LPA_Data\golden*, and press **OK**.

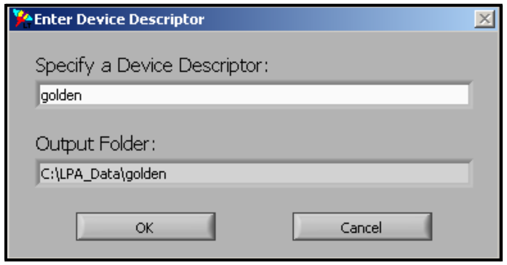


*Figure 6-6. Clicking the **Save** button in the main window calls up the **Device Descriptor** window.*

Changing from a Configuration File to a Reference File

Now that we have made changes to the tolerances in a data file, we can save that file as the new **Reference**. Select **Setup > File Configuration** from the main menu to view the **Specify File Paths** window (Figure 6-2). Click the **Compare to Reference Trace** checkbox. Click the **Reference Trace Folder** browse button and select the folder *C:\LPA_Data\golden* from the **Specify Folder Containing Reference Trace** window (Figure 6-7). Note that you are selecting the folder itself, and not a specific file in the folder.

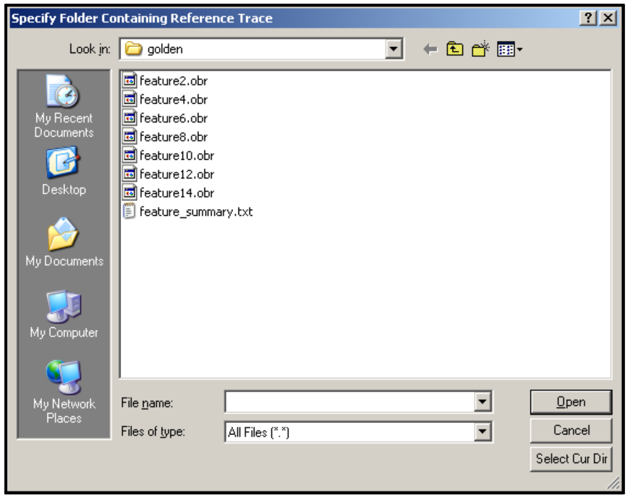


*Figure 6-7. The **Specify Folder Containing Reference Trace** window appears after clicking the browse button in the **Specify File Paths** window.*

Use the **Select Cur Dir** button to select the folder once you have navigated to it. This returns you to the **Specify File Paths** window. Uncheck the **Use General Tolerances** checkbox.

A **Reference Trace** contains both general tolerance values (like the ones in the **Parameter Configuration File**) and tolerances that are specific to each individual feature. This box can be checked to use the **General Tolerances** instead of the feature-specific tolerances. (It is usually desirable to use the feature-specific tolerances with a **Reference Trace**, but comparing to general tolerances is sometimes useful.)

Click **OK** to accept the new configuration. The current trace will be reprocessed. No changes will be seen at this time, however, because the trace is being compared to itself.

Editing Feature-Specific Tolerances

The main advantage of using a **Reference Trace** instead of **General Tolerance** values is that each individual feature can have its own tolerance range. To assign these values, select **Setup > Feature-Specific Tolerance** from the main menu, which opens the **Tolerance Specification** window (Figure 6-8).

6

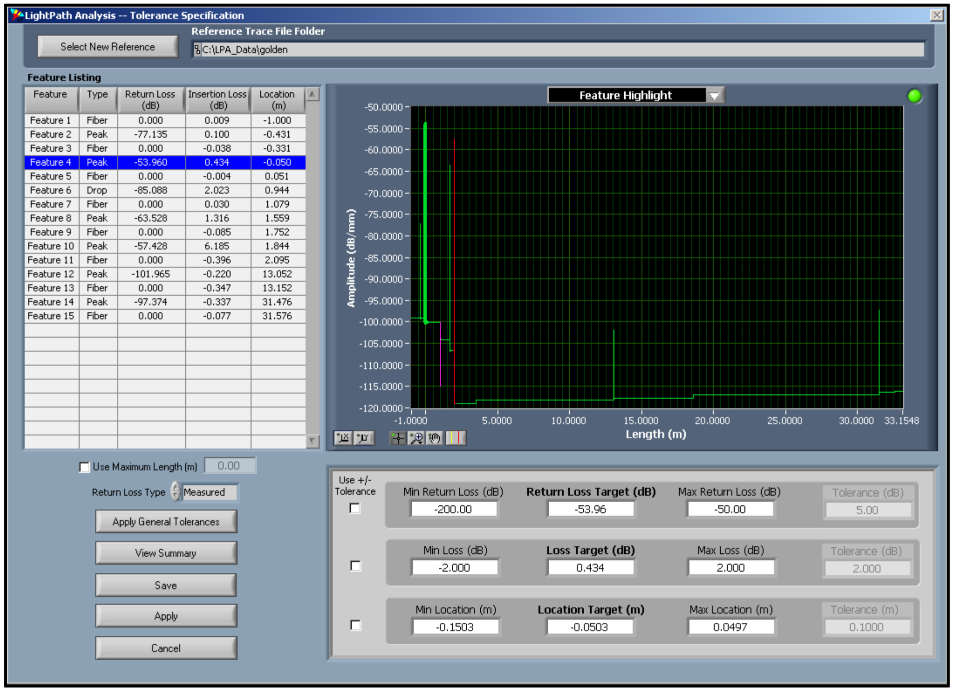
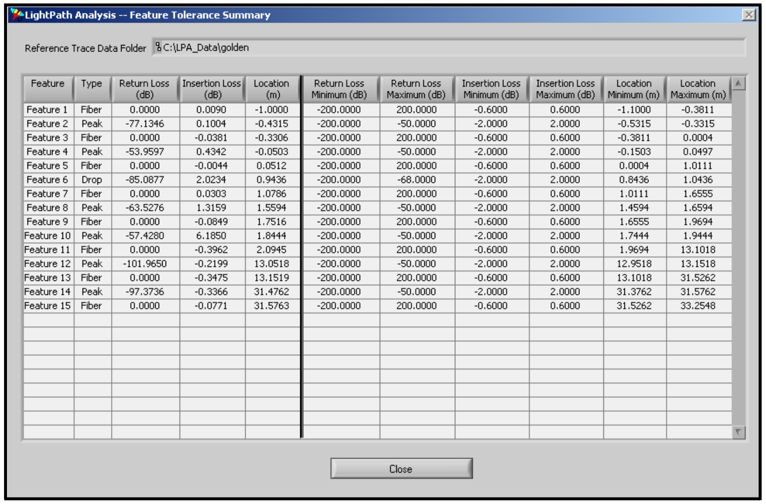


*Figure 6-8. Selecting **Setup > Feature-Specific Tolerance** from the main menu calls up the **Tolerance Specification** window above.*

This window shows a detailed view of each of the segments found in the **Reference Trace**. The **Feature Listing** grid shows the actual **Return Loss**, **Loss** (i.e. insertion loss) and **Location** for each feature. These **Target** values are also shown in the area at the lower right, along with the tolerated minima and maxima. Note that the upper of the three regions is blank for fiber sections, which have a **Return Loss** of zero.

The **Min** and **Max** values to the sides of the **Targets** represent the range of values that will be considered passing for this particular feature. Any **Min** or **Max** values that have been exceeded will appear in red.

In our example, all of the **Min** and **Max** values are currently based on the **General Tolerances** used when last evaluating the trace. Press the **View Summary** button to view all of the feature details in one window, the **Feature Tolerance Summary** (Figure 6-9).


LightPath Analysis -- Feature Tolerance Summary

Reference Trace Data Folder C:\LPA_Data\golden

Feature	Type	Return Loss (dB)	Insertion Loss (dB)	Location (m)	Return Loss Minimum (dB)	Return Loss Maximum (dB)	Insertion Loss Minimum (dB)	Insertion Loss Maximum (dB)	Location Minimum (m)	Location Maximum (m)
Feature 1	Fiber	0.0000	0.0090	-1.0000	-200.0000	200.0000	-0.6000	0.6000	-1.1000	-0.3811
Feature 2	Peak	-77.1346	0.1004	-0.4315	-200.0000	-50.0000	-2.0000	2.0000	-0.5315	-0.3315
Feature 3	Fiber	0.0000	-0.0381	-0.3306	-200.0000	200.0000	-0.6000	0.6000	-0.3811	0.0004
Feature 4	Peak	-53.9597	0.4342	-0.0503	-200.0000	-50.0000	-2.0000	2.0000	-0.1503	0.0497
Feature 5	Fiber	0.0000	-0.0044	0.0512	-200.0000	200.0000	-0.6000	0.6000	0.0004	1.0111
Feature 6	Drop	-85.0877	2.0234	0.9436	-200.0000	-68.0000	-2.0000	2.0000	0.8436	1.0436
Feature 7	Fiber	0.0000	0.0303	1.0786	-200.0000	200.0000	-0.6000	0.6000	1.0111	1.6555
Feature 8	Peak	-63.5276	1.3159	1.5594	-200.0000	-50.0000	-2.0000	2.0000	1.4594	1.6594
Feature 9	Fiber	0.0000	-0.0849	1.7516	-200.0000	200.0000	-0.6000	0.6000	1.6555	1.9694
Feature 10	Peak	-57.4280	6.1850	1.8444	-200.0000	-50.0000	-2.0000	2.0000	1.7444	1.9444
Feature 11	Fiber	0.0000	-0.3962	2.0945	-200.0000	200.0000	-0.6000	0.6000	1.9694	13.1018
Feature 12	Peak	-101.9650	-0.2199	13.0518	-200.0000	-50.0000	-2.0000	2.0000	12.9518	13.1518
Feature 13	Fiber	0.0000	-0.3475	13.1519	-200.0000	200.0000	-0.6000	0.6000	13.1018	31.5262
Feature 14	Peak	-97.3736	-0.3366	31.4762	-200.0000	-50.0000	-2.0000	2.0000	31.3762	31.5762
Feature 15	Fiber	0.0000	-0.0771	31.5763	-200.0000	200.0000	-0.6000	0.6000	31.5262	33.2548

Close

*Figure 6-9. The user may view this **Tolerance Summary** by clicking the **View Summary** button in the **Tolerance Specifications** window (Figure 6-8).*

Notice that the **Return Loss Maximum** for each peak is set to -50, the value you set as the **Peak Tolerance** for the **Parameter Configuration File**, using in the **Parameter Specifications** window shown in Figure 6-4 on page 83. However, we left the **Drop Tolerance** at -68 in the **Parameter Specifications** window, as confirmed in the **Feature Tolerance Summary** above.

Click the **Close** button to exit the **Feature Tolerance Summary** window.

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The minimum and maximum values should be set so that all segments of the **Reference Trace** pass, and with a wide enough range so that all segments of any good trace would be expected to pass.

The pull-down menu in the **Tolerance Specification** window graph (Figure 6-8) can be used to change the display. The **Feature Highlight** option shows all of the feature segments. The **High Resolution Data** option shows the amplitude plot for whichever feature was highlighted in the **Feature Listing** grid.

Note that no amplitude data is stored for fiber segments. The message **No Data to Display** will be shown if a fiber segment is selected with the **High Resolution Data** graph active.

Use the pull-down menu to change the graph back to **Feature Highlight**. The feature data is shown, scaled to the actual width of that feature. Press the X-axis  autoscale button to show the entire feature graph.

The minimum and maximum values can be set numerically from the **Tolerance Specification** window. The **Use +/- Tolerance** checkboxes change the **Min** and **Max** value for a particular item (**Return Loss**, **Insertion Loss**, or **Location**) based on the **Target** value and a **Tolerance** value.

Select **Feature 6 and** click the **Use +/- Tolerance** checkbox to the left of the **Min Loss (dB)** control. The **Min Loss (dB)** and **Max Loss (dB)** controls are now disabled and their values have been changed 2 dB below and above the **Loss Target (dB)** value.

The **Tolerance (dB)** control is now enabled. Change its value to 1.0 and observe that the **Min Loss (dB)** and **Max Loss (dB)** values are changed to be 1.0 dB below and above the **Loss Target (dB)** value.

Hint

If you wanted to change the **Tolerance** ranges for **Loss** another **Feature** to +/- 1.0 from the **Loss Target**, simply highlight that **Feature** in the **Feature Listing** while the **+/- Tolerance** checkbox is still checked.

Uncheck the **Use +/- Tolerance** checkbox. The **Min Loss (dB)** and **Max Loss (dB)** controls are now enabled again. The values are still set to 1 dB above and below the target value, but their values can now be changed if desired.

The **Apply General Tolerances** button in the lower left region sets all minimum and maximum values to match the general tolerances held in the reference trace file. Press the **Apply General Tolerances** button and observe that the **Min Loss (dB)** and **Max Loss (dB)** values have returned to their original values. (For details on view and modifying the **General Tolerances** of the **Reference Trace**, see “Editing a Reference Trace: Processing Parameters and General Tolerances” on page 94.)

Make the two failing features pass by changing the **Max Loss (dB)** value for **Feature 6** to 3.0, and the **Max Loss (dB)** value for **Feature 10** to 7.0. Click **Save**.

The new tolerance values are written to the files in the *golden* folder, and the current trace is reprocessed using these new values. Since the trace data is still the same as that in the *golden* **Reference Trace**, the lower graph should show all features as passing.

Comparing a New Trace to the Reference

After loading and modifying a **Reference Trace**, you would generally proceed to scanning data, which would automatically be compared to the **Reference Trace**. But for this tutorial, we will load another *.obr file similar to the one used above to create the **Reference Trace**.

Select **File** > **Load Data File** from the menu; browse and open the file *device2.obr*, located in *C:\Documents and Settings\All Users\Application Data\Luna Technologies\LightPath Analysis v#.#*. The new trace should be similar to the first, but may differ slightly. If you set the **Loss** tolerances as directed above, all the features should be marked as passing.

Viewing Segment Details

Press the **Compare** button to view the **Trace Comparison** window (Figure 6-10). Note that because you have loaded a **Reference Trace Event Listing** now contains data. (Earlier in the tutorial we were comparing to a **Parameter Configuration File**, so this grid was empty.) The **Reference Trace File Folder** field in the upper left shows the current **Reference Trace** (*C:\LPA_Data\golden*).

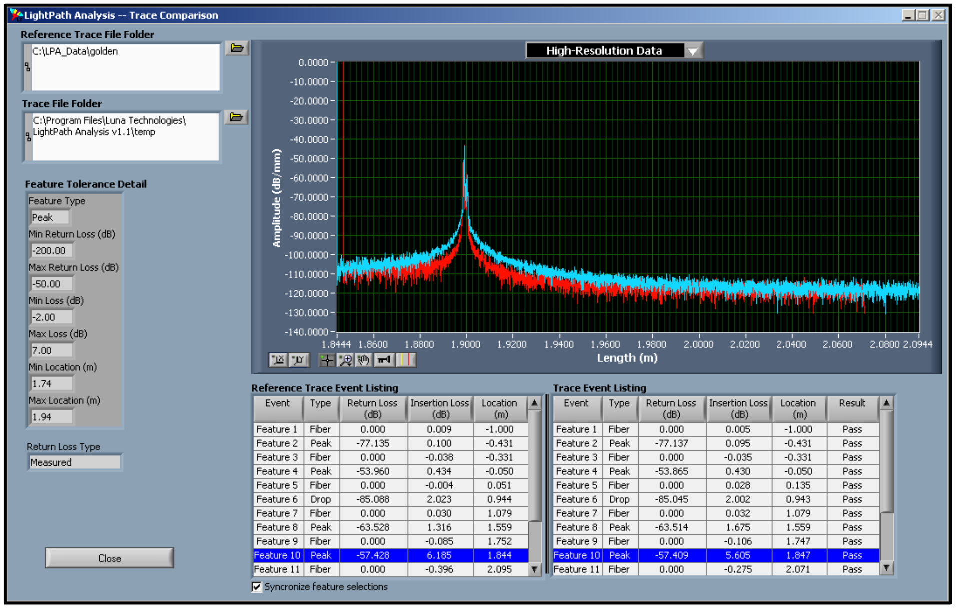


*Figure 6-10. The **Trace Comparison** window, with the graph pull-down menu set to **High Resolution Data**. The **Reference** data shows in blue, and the loaded trace shows in red.*

Select several different features using either the **Event Listing** grids or the vertical cursors with the cross-hair tool. Use the pull-down menu to select show the **High Resolution Data**, which will compare two features with more detail. The **Reference** data is shown in blue, and the loaded trace in red. View the **High-Resolution Data** for all the peak and drop features. (Remember that no **High-Resolution Data** is saved for fiber segments.)

Press the **Close** button at the lower left to exit the **Trace Comparison** window. In the main window, click the **Save LightPath Files** button in the lower left. Enter *device2* as the descriptor and then click **OK**. This data will be saved to the folder *C:\LPA_Data\device2*. This data can be used later as a **Reference Trace**, or can be used as documentation of how the particular device compared to the **Reference Trace**.

Comparing a Failing Trace to the Reference

Load the file *device3.obr* (**File > Load Data File**). This file is similar to *device1.obr* but shows an extra peak around 0.54 meters. Press the **Compare** button to view the **Trace Comparison** window.

The **Reference Trace Event Listing** and **Trace Event Listing** entries are ordered so that matching features are aligned. The extra peak and fiber segment in *device3.obr* are shown in **Trace Event Features 6** and **7**, which have no corresponding entries in the **Reference Trace Event Listing**. If a trace had missing features, they would be displayed as features in the **Reference Trace Event Listing** with no corresponding features in **Trace Event Listing**.

Select each of the features to verify that the extra peak and fiber are the only failing features. In the **Feature Tolerance Detail** area on the left, the extra features should show as failing (red) both in **Feature Type** and **Location**. Note that the **Min** and **Max Loss** values for the extra features have been compared to the **Reference Trace's General Tolerance** values, since there is no reference feature to compare them to. When **Feature 6** of *device3.obr* is shown as **High Resolution Data** (using the graph pull-down menu), only red data is displayed, since there is no **Reference Trace** (blue) data saved at that location.

Comparing Traces Using the Trace Comparison Window

From the **Trace Comparison** window, one can open and compare other files without using the **File > Load Data File** command or the **Setup > File Configuration** command in the main window. Comparing other files in the **Trace Comparison** window only changes the **Reference Trace** or compared data temporarily. When this window is closed, the software returns to the data loaded using the **File > Load Data File** command, and to the Reference Trace chosen in the **Specify File Paths** window (Figure 6-2 on page 80).

To compare the current **Reference** to a different trace, press the browse button to the right of the **Trace File Folder** control and select the directory *C:\LPA_Data\device2*. This compares the reference file to the device2 files created earlier in the tutorial. All features should be again be marked as passing.

Similarly, you can use the **Reference Trace File Folder** browse button to select a different **Reference** for comparison to the current trace. By using both controls to select two different folders, any reference or evaluation trace can be compared to another. (However, it is of limited use to compare two traces unrelated to either the current reference or the currently loaded trace.)

Press the **Close** button to exit the Trace Comparison window. Note that the loaded trace is still *device3.obr*, and the lower graph data is not reprocessed.

Press the **Save LightPath Files** button to save the LightPath data for *device3.obr*. Enter *device3* as the descriptor for new data folder, and press **OK**.

Editing a Reference Trace: Processing Parameters and General Tolerances

Above under “Editing Feature-Specific Tolerances” on page 88, you learned how to edit feature-specific tolerances in the **Reference Trace**. Reference files also contain processing parameters and general tolerance values like those in the **Parameter Configuration File**. These values can be modified to affect the way features are detected, and to change general tolerances.

Select **Setup > Data Processing Parameters** from the main menu. The **Parameter Specifications** window is shown again (Figure 6-4 on page 83), this time displaying the parameters and tolerances contained in the **Reference Trace** file “*golden*.”

The **Processing Parameters** and **General Tolerances** for the *golden* reference are currently the same values (contained in *lpa_default_params.ini*) that were in use when the trace was saved. These values can be changed so that future traces being compared to the **Reference Trace** file “*golden*” will be processed using a different set of parameters and tolerances.

Changing the **General Tolerances** for a **Reference Trace** will change the tolerance values used to evaluate extra features. For example, changing the value of **(IL) Loss Tolerance (dB)** to 3.5 would cause the extra feature in *device3.obr* to pass based on (insertion) **Loss** (although it would still fail for being a feature not present in the **Reference Trace**). More importantly, these are the values that would be used if both the **Compare to Reference Trace** and **Use General Tolerances** checkboxes were selected in the **Specify File Paths** window (Figure 6-2 on page 80).

Change the **Processing Parameters** in a **Reference Trace** with caution, because new traces will be processed differently from the way the original **Reference Trace** was processed. For example, changing the **Feature Extract Length (m)** back to 0.1 would collapse the two peaks at 1.6 and 1.9 m back into a single feature when processing any new data. This would make it impossible for any new trace to match the **Reference**, which would still retain the two distinct peaks.

The **Reference Trace Processing Parameters** should be changed only to correct a situation in which good devices are failing because of mismatched features caused by random but acceptable variations between devices.

Important

Ideally, many devices should be tested before a **Reference Trace** *is settled upon*, to make sure that the **Processing Parameters** being used will result in a consistent set of features for every good device tested. It should then be unnecessary to modify the **Reference Trace** later.

Press **Cancel** to exit the **Parameter Specifications** window without modifying the **Reference** file.

Setting the Maximum Device Length

Sometimes there may be trailing noise present in a trace after all of the actual features. Differences in this noise level may cause the LightPath Analysis software to conclude that a trace has failed, even though all of the desired features are within the correct limits. In these cases, it is advantageous to specify a **Maximum Length** beyond which no features will be compared.

To specify this value, select **Setup** > **Data Processing Parameters** from the main menu. Verify that *C:\LPA_Data\golden* is still the selected **Reference Data Folder** at the top of the **Parameter Specifications** window (Figure 6-4 on page 83). In the **Device Length** section at the lower left, check the **Use Maximum Length** checkbox and change the value of **Maximum Length** to 5.0. Press **Apply** to re-evaluate the current trace (still *device3.obr*) without re-saving the **Reference**. The trace will be reprocessed but will only display up to the last feature within 5.0 meters.

Note

Although the **Maximum Length** is set to 5.0, the last **Peak** ends at just over 2 meters. The software omits the trailing **Fiber** segment, showing only the data up to the end of the last **Peak** or **Drop**.

The **Trace Comparison** window (Figure 6-10 on page 92) will also show only the features occurring before the **Maximum Length**.

The **Maximum Length** value can also be modified through the **Tolerance Specification** window (Figure 6-8 on page 88) Select **Setup** > **Feature-Specific Tolerances** from the main menu. Click in the **Use Maximum Length** checkbox just below the **Feature Listing** grid, then type in the desired maximum. Notice that all trace segments are shown in the **Tolerance Specification** window. This aids in correctly setting the **Maximum Length**.

Change the **Maximum Length** value back to 0.0 and uncheck the **Use Maximum Length** checkbox. Press the **Apply** button to reprocess the trace without saving the changes to the **Reference Trace**. The trace will be reprocessed and will now show all features.

Resetting the Default Parameters

Since some of the default processing values were changed in this walk-through, take the following steps to return them to their original values before using this tutorial again.

From the main menu, select **Setup > Data Processing Parameters** to view the **Parameter Specifications** window. Press the **Select New Reference** button at the top left to load a different **Reference** or **Parameter Configuration File**. Select the file *lpa_default_params.ini* located in the folder *C:\Documents and Settings\All Users\Application Data\Luna Technologies\LightPath Analysis v#.#*.

In the **Peak Processing Parameters** section, change the **Feature Extract Length** from 0.05 back to 0.1. In the **General Tolerances** section, change the **(RL) Peak Tolerance** value from -50 to -65, and change the **(IL) Splice Loss Tolerance** value from 0.6 to 0.1.

Press the **Save** button. Select the file *lpa_default_params.ini* and press **Save**.

Note that the data is not reprocessed, because the software is still using the *golden* trace as the **Reference**. Selecting a new **Reference** in the **Parameter Specifications** window or in the **Tolerance Specification** window only selects a new file to edit, and does not change the file being used for processing. The **Reference** or **Parameter Configuration File** used for processing can only be changed using the **Specify File Paths** window (Figure 6-2 on page 80).

To reset *lpa_default_params.ini* as the file used to process traces, select **Setup > File Configuration** from the main menu to view the **Specify File Paths** window, and uncheck the **Compare to Reference Trace** checkbox. Make sure that *lpa_default_params.ini* is listed as the **Parameter Configuration File** and press **OK**.

Suggested Setup and Use

As already discussed, the LightPath Analysis software is designed to compare devices to an ideal **Reference Trace** for quality control purposes. Ideally, the **Reference Trace** and all test scans for a given device or component should be stored in the same base folder, with the **Reference Trace** in a "*golden*" subfolder, and test results stored in subfolders labeled with the serial number of the test device.

The suggested setup is procedure is as follows:

1. Select **Setup > File Configuration**. In the **Specify File Paths** window (Figure 6-2 on page 80), change the **Base Folder for Output Files** to the name or model number of the part to be tested.
2. **Scan** several devices to determine the processing parameters required to achieve a consistent feature list across multiple devices. Determine the desired and achievable tolerance levels.
3. Select **Setup > Data Processing Parameters** from the main menu. Set the parameters and tolerances in the **Parameter Specifications** window (Figure 6-4 on page 83)
4. **Scan** an ideal device, and save its results to the *golden* subfolder. Select **Setup > File Configuration** and select this trace as the reference.
5. Modify the **Feature-Specific Tolerances** for the *golden* trace to match the test requirements in the **Tolerance Specification** window (Figure 6-8 on page 88).
6. Scan test devices. Note the pass/fail result of each device. Save the LightPath files for each device, using the device's serial number as the subfolder name.

Description of Processing Parameters and Tolerances

This section describes the various processing parameters and tolerances, and their affects on the feature detection algorithm. The explanatory graphs below may also be viewed from the software by clicking the question button  next to any parameter or tolerance setting in the **Parameter Specifications** window (Figure 6-4 on page 83).

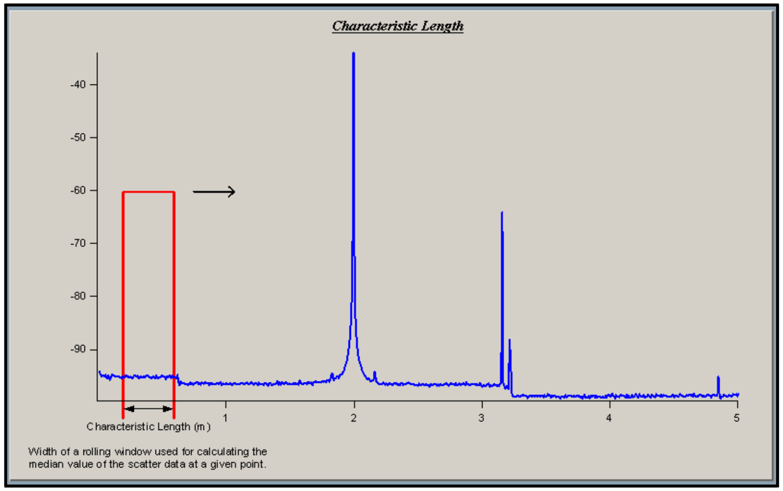
Characteristic Length (m)

A window is passed across a raw data set to find the “rolling median” of that data. The width of the window is defined as a number of points corresponding to the **Characteristic Length** specified by the user. This calculation of the rolling median is performed in order to locate the peaks (i.e. upward events) within the data set.

As this value is increased, the median algorithm will tend to smear the events of a given data set, making it less able to distinguish between events (i.e. the median will not transition quickly enough). As this value is decreased, the median will react too quickly to events in the given data set and will tend to track each transient event.

Default Value: 0.1 meters

Closely Related To: **Peak Detect Ratio**

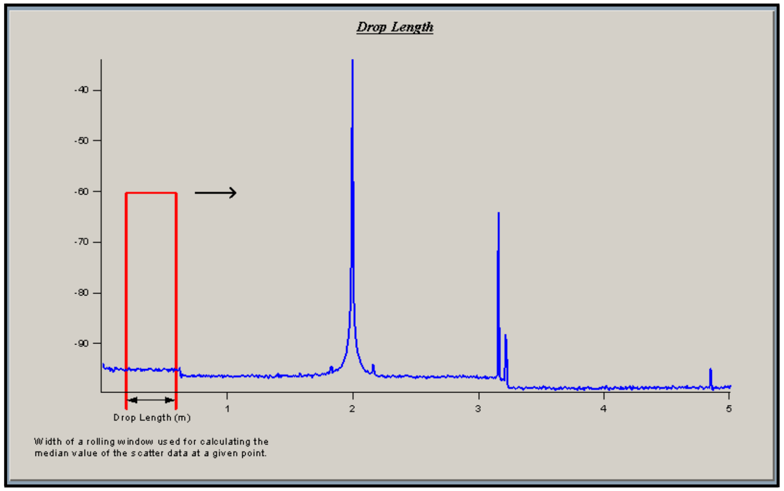


Drop Length (m)

The **Drop Length** is similar to the **Characteristic Length** discussed above, in that it is the length of a window used to calculate a rolling median of the data set. However, the **Drop Length** is used to resolve drops in the raw scatter data by comparing the rolling median value obtained from this calculation with the rolling median value calculated using the **Characteristic Length**. The **Drop Length** value must be significantly smaller than the value specified for the **Characteristic Length**, or a drop may not be detected.

Default Value: 0.02 meters

Closely Related To: Drop Detect Ratio, Drop Tolerance



Feature Extract Length (m)

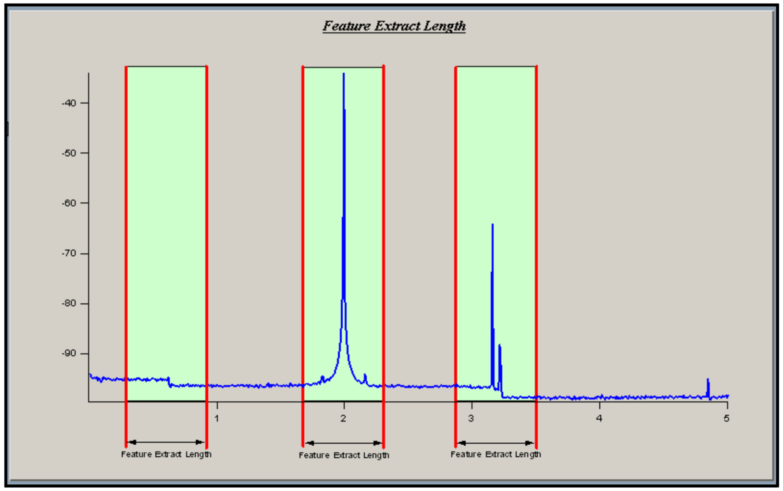
Once a **Peak** or other feature is detected by the software, a segment of data is extracted around that location for further processing. The length of this segment is specified by the **Feature Extract Length** parameter specified by the user.

Primarily, this parameter is used for processing of **Peak** features that are found in the data set. However, this value is also be used as the area over which to calculate the **Return Loss** of all features. It is used in determining whether the **Drop Tolerance** and **Peak Tolerance** criteria are violated by each feature.

If two peaks are found close to each other and the extracted segments around those peaks overlap, the peaks are combined into a single feature.

Default Value: 0.1 meters

Closely Related To: **Peak Dead Zone, Peak Tolerance, Drop Tolerance**



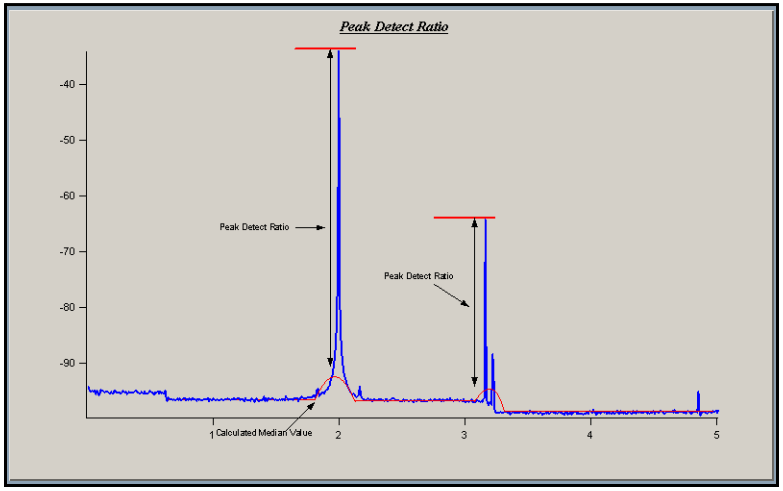
Peak Detect Ratio (lin)

The **Peak Detect Ratio** is the ratio of the raw data value to the calculated median value that denotes a peak at that location. This ratio is calculated at each data point. Calculated ratios that are above this specified value are recorded as **Peaks**.

Calculation: raw data amplitude / median value

Default Value: 40

Closely Related To: **Characteristic Length**

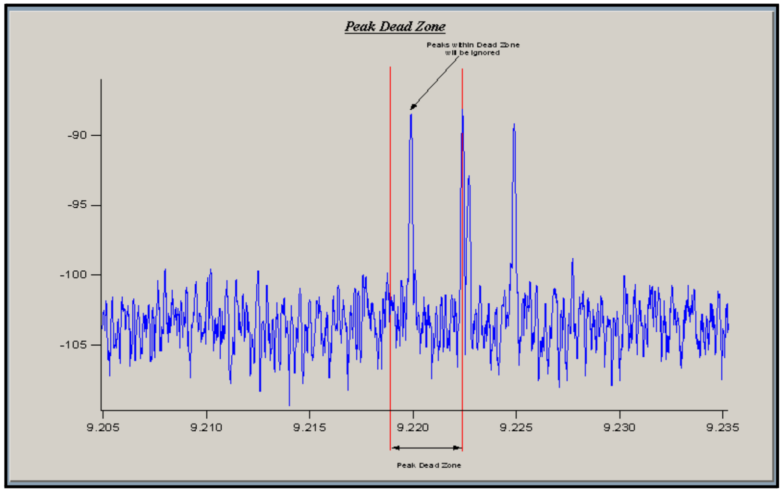


Peak Dead Zone (m)

The **Peak Dead Zone** is the length within the scatter data set in which the software will not look for another **Peak** while processing an extracted segment around a **Peak**.

Default Value: 0.005 meters

Closely Related To: **Feature Extract Length**



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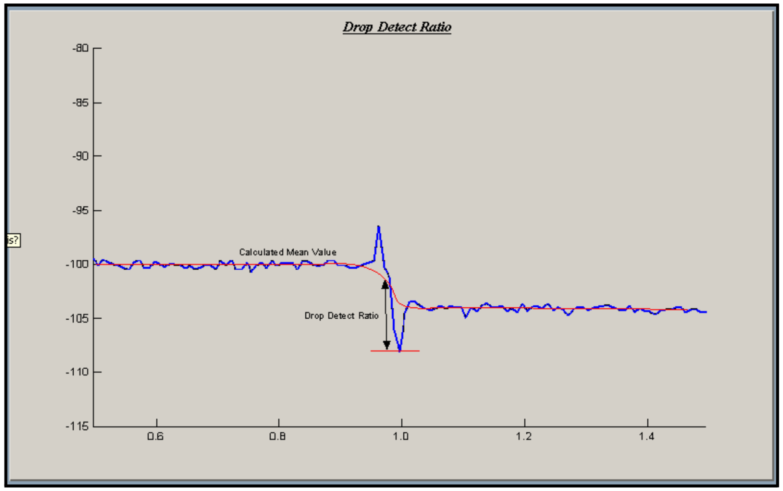
Drop Detect Ratio (lin)

The **Drop Detect Ratio** is the ratio between the raw scatter data and the median value. The ratio between these two values is calculated at all data points and a drop is detected when the calculated value is greater than this criteria.

Calculation: raw data amplitude / median value

Default Value: 1.5

Closely Related To: **Drop Size, Drop Tolerance**

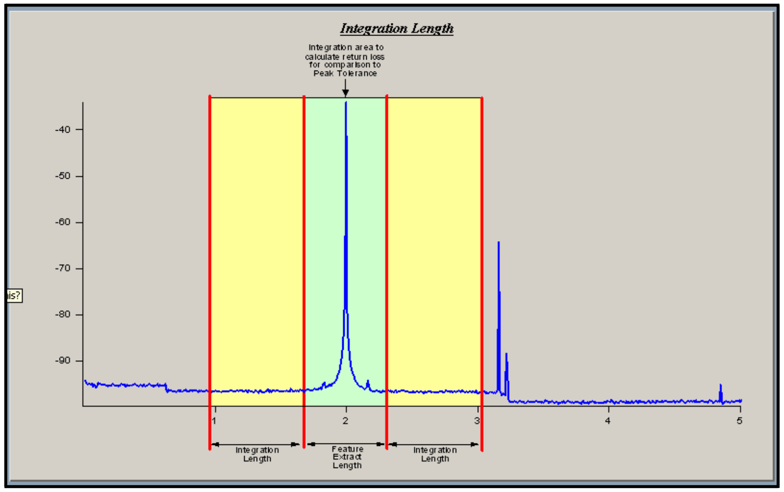


Integration Length (m)

The **Integration Length** parameter is the length of the data set over which the integrated power is calculated for the purpose of detecting the location of splice losses in the data. It is also the length used when performing the same calculations to find the insertion loss across all artifacts that were determined to be **Peaks**.

Default Value: 0.5 meters

Closely Related To: **Splice Loss Tolerance, Loss Tolerance**



Return Loss Type

The software can use two methods to calculate **Return Loss**:

- **Measured Return Loss:** The actual power reflected from an event as detected by the OBR. If **Insertion Loss** has occurred before a **Return Loss**, the power reflected from that event is reduced. The **Measured Return Loss** includes this reduction.
- **Absolute Return Loss:** The amount of loss reflected from an event in the absence of **Insertion Loss** up to that event. The **Absolute** method shows **Return Loss** data as if each connection was attached directly to the front of the OBR, with nothing before it.

You may change the **Return Loss** calculation method in the **Parameter Specifications** window (Figure 6-4 on page 83).

Why is there an asterisk before the RL value?

When the vertical cursors are on in the main window, the **Return Loss** of a highlighted feature will be displayed in the upper right of the graph. Sometimes there will be an asterisk (*) before this value, meaning that the Rayleigh scatter just before that event was not sufficiently flat to allow accurate **Absolute Return Loss** calculation.

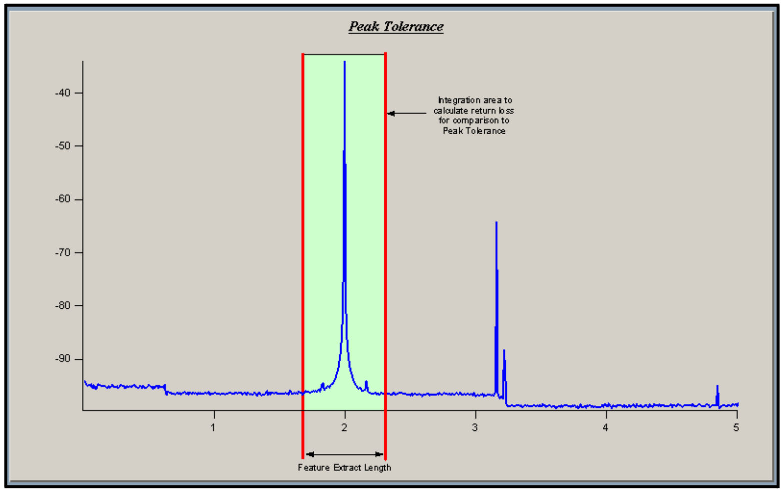
An asterisk may also be placed before the **Return Loss** value if the gain is set low enough that the Rayleigh scatter cannot be detected properly.

Peak Tolerance (dB)

The **Peak Tolerance** value is equivalent to the **Maximum Return Loss** allowed by all artifacts in the data set. If the return loss of any artifact surpasses this tolerance, it will be shown to fail.

Default Value: -65 dB

Closely Related To: **Feature Extract Length, Peak Dead Zone**

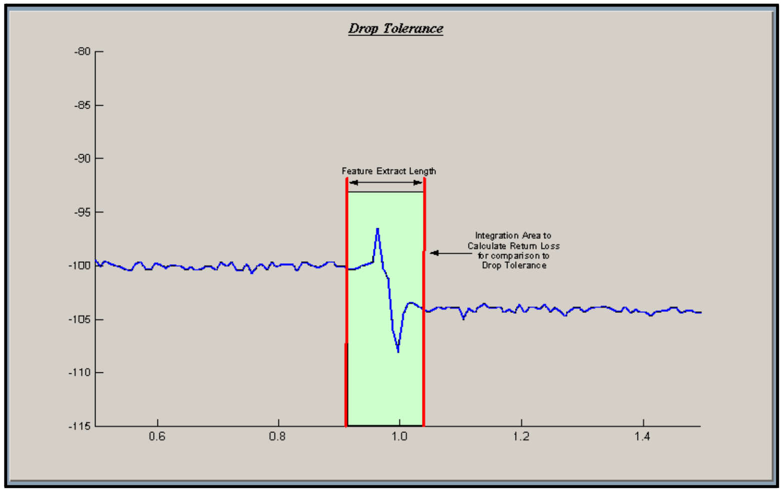


Drop Tolerance (dB)

The **Drop Tolerance** is equivalent to the **Maximum Return Loss** that is allowable for any **Drop** detected in the scatter data. The return loss of a **Drop** is calculated by integrating the power of an area centered around the feature that has a length equivalent to the **Feature Extract Length**.

Default Value: -68 dB

Closely Related To: **Feature Extract Length**

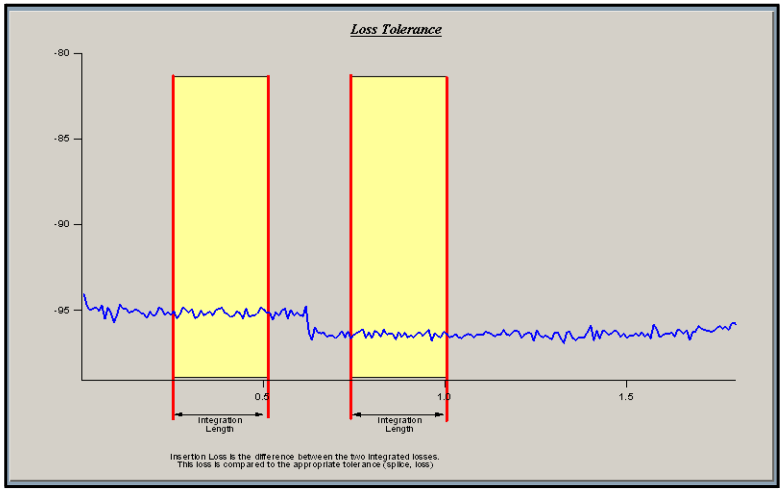


Loss Tolerance (dB)

The **Loss Tolerance** is the maximum allowable insertion loss across any interface in the data set.

Default Value: 2.0 dB

Closely Related To: **Splice Loss Tolerance, Integration Length**



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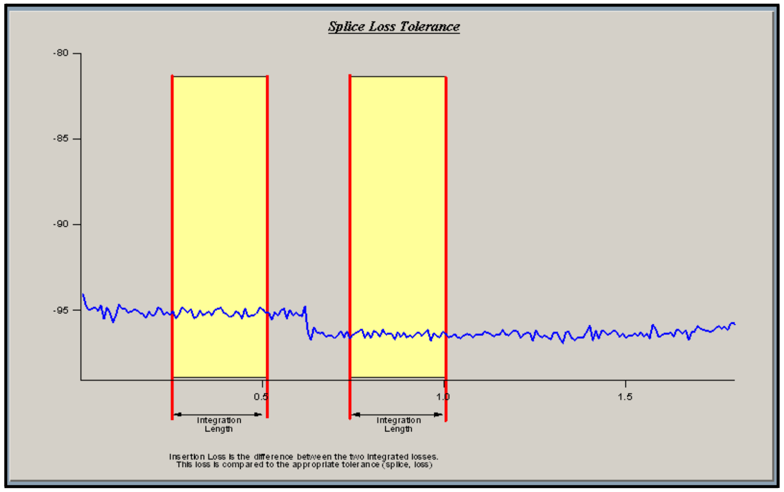
Splice Loss Tolerance (dB)

The **Splice Loss Tolerance** is the maximum allowable insertion loss for splices found in a data set.

Default Value: 0.2 dB

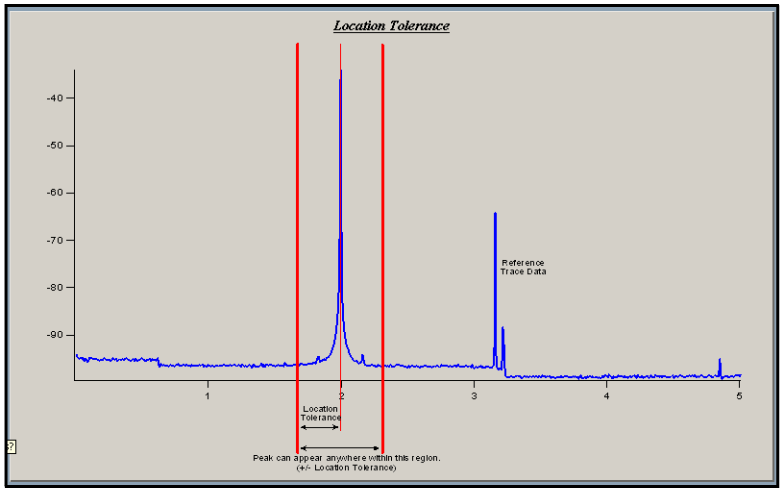
Closely Related To: **Loss Tolerance, Integration Length**



Location Tolerance (m)

The **Location Tolerance** is the maximum distance a feature may be from its expected location (based on the **Reference** or *golden* trace location) and still be considered passing.

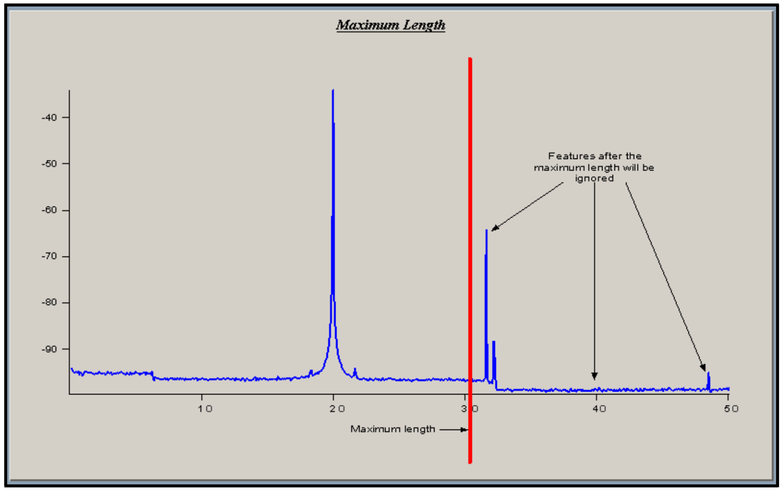
Default Value: 0.1 m



Maximum Length (m)

Features after the **Maximum Length** will not be displayed, when this item is checked in the **Parameter Specifications** window (Figure 6-4 on page 83) or the **Tolerance Specification** window (Figure 6-8 on page 88). Only the last **Peak** or **Drop** before this length will be displayed.

Default Value: 0.0 m



6

Remote Commands

All of the remote commands available in the OBR control software (See Chapter 7, “Controlling the OBR Remotely,” on page 119) are also available in the LightPath Analysis software, ***except** the following*:

CONF:COEF

CONF:COEF?

SYST:COPY

FETC:FDTL?

Remote Commands Unique to LPA

FETCh:NUMberofFeatures?

Usage: FETC:NUMF?

Description: Queries the number of features present in the current LightPath trace.

Response: Returns a number indicating the number of features in the trace. Returns an error message if no trace data has been loaded.

Example: FETC:NUMF?

15

The response indicates that the current trace has 15 features.

FETCh:FEATures

Usage: FETC:FEAT?

Description: Retrieves the LightPath features for the current trace.

Response: A table listing the details for each trace feature. The first line is a header listing the names of each column. The remaining lines list the values for each feature. Lines are separated by newline characters, and columns by tab characters.

Example: CONF:FEAT?

Feature\tType\tRet Loss\tIns Loss\tLocation\tRet Loss Min\tRet Loss Max\tIns Loss Min\tIns Loss Max\tLocation Min\tLocation Max\tPass/Fail

Feature 1\tFiber\t0\t0.0045922\t-1.00003\t0.568596\t-200\t200\t-0.6\t0.6\t-1.10003\t-0.381055\tPass

Feature 2\tPeak\t-77.1366\t0.0945949\t-0.4314\t0.100805\t-200\t-50\t-2\t2\t-0.531477\t-0.331477\tPass

Feature 3\tFiber\t0\t-0.0347541\t-0.330557\t0.280291\t-200\t200\t-0.6\t0.6\t-0.381055\t0.000424449\tPass

…

(\t indicates a tab character)

FETCh:PASSed?

Usage: FETC:PASS?

Description: Queries whether the current LightPath trace has passed. That is, is all of the features have passed.

Response: Returns a 1 if all features have passed, or 0 if one of more features have failed. Returns an error message if no trace data has been loaded. If the response is 0, the FETC:FEAT? query can be used to determine which of the features has failed and why.

Example: FETC:NUMF?

1

The response indicates that all of the features have passed.

FETCh:GeneralTOLerances?

Usage: FETC:GTOL?

Description: Queries the general tolerances contained in the current reference trace or parameter file.

Response: Returns the Peak, Drop, Loss, Splice Loss, and Location Tolerances for the current reference or parameter file.

Example: FETC: GTOL?

Peak Tolerance: -50

Drop Tolerance: -68

Loss Tolerance: 2

Splice Loss Tolerance: 0.6

Location Tolerance: 0.1

CONFigure:ConfFiGuration?

Usage: CONF:CFG?

Description: Queries the current LightPath configuration.

Response: Strings indicating the current reference trace directory, default parameter file, “using reference” setting, “using general tolerances” setting, and base output folder.

Example: CONF:CFG?

Reference directory: C:\LPA_Data\golden

Default params: C:\LPA\LPA_default_params.ini

Use reference: 1

Use general tolerances: 0

Base folder: C:\LPA_Data

The response shows the current reference trace directory and the default parameter filename. The “Use Reference:1” response indicates that the reference trace is being used (instead of the default parameters file). The “Use general tolerances: 0” response indicates that the feature specific tolerances are being used (instead of the general tolerances.) The “Base folder” response shows the directory where LightPath data will be saved.

CONFigure:ConfFiGuration

Usage: CONF:CFG {*refDir, defParamFile, useRef, useGenTol, baseFolder*}

Description: Sets the current LightPath configuration.

6

The parameter *refDir* specifies the directory containing the reference trace. The name must be in quotes if it contains any spaces. If this parameter is specified as “”, the current reference trace will be retained.

The parameter *defParamFile* specifies the default parameter filename. The name must be in quotes if it contains any spaces. If this parameter is specified as “”, the current parameter file will be retained.

The parameter *useRef* specifies whether acquired traces are compared to the reference trace or to the default parameter file. A value of 1 indicates that the reference trace should be used. A value of 0 indicates that the default parameter file should be used.

The parameter *useGenTol* specifies whether acquired traces are compared to a reference trace's general tolerances or to its feature-specific tolerances. A value of 1 indicates that the general tolerances should be used. A value of 0 indicates that the feature-specific tolerances should be used. This parameter is not meaningful if setting useRef to 0.

The parameter *baseFolder* specifies the base folder where LightPath data files will be saved.

Response: None

Example: CONF:CFG C:\LPA_Data\myref, C:\LPA\myparams.ini, 1, 0, C:\LPA_Data

Sets the reference trace to “C:\LPA Data\myref” and the default parameter file to “C:\LPA\myparams.ini”. Specifies that the reference trace should be use, and that the feature specific tolerances should be used.

CONF:CFG “”, “C:\test\myparams.ini”, 0

Sets the default parameter file to “C:\LPA\myparams.ini”, and specifies that the default parameter file should be used to evaluate traces. The reference trace directory, base folder, and useGenTol setting are not changed.

CONF:CFG “”, “”, 1, 0

Specifies that traces should be evaluated using the current reference trace and the feature-specific tolerances. The reference trace, default parameter file, and output base folder are not changed.

CONFigure:REFerencetrace?

Usage: CONF:REF?

Description: Queries the current LightPath reference trace.

Response: The current reference trace directory.

This information can also be obtained using the CONF:CFG? query. Since querying the reference trace is a more common operation, it is provided its own query for convenience.

Example: CONF:REF?

C:\LPA_Data\golden

Indicates that “C:\LPA_Data\golden” is the current reference trace. Note that this response does not indicate that the reference trace (rather than the default parameter file) is being used to evaluate traces. That information can be determined using the CONF:CFG? query.

CONFigure:REFerencetrace

Usage: CONF:REF {*refDir*}

Description: Sets the current LightPath reference trace, and sets the LightPath software to evaluate traces using the reference trace rather than the default parameter file.

If the *refDir* parameter is not a fully qualified path, it is assumed to be subdirectory in the Base Folder—the directory where LightPath data files are saved.

Note that this could be also be accomplished using the command CONF:CFG {refDir, "", 1}.

Since changing the reference trace is a more common operation, it has its own command for convenience.

Response: None.

Example: CONF:REF C:\LPA_Data\golden

Sets the reference trace to "C:\LPA_Data\golden" and configures the software to use it (rather than the default parameter file) to evaluate traces.

CONF:REF myRef

Sets the reference trace to the "myRef" subdirectory in the Base Folder. If this folder is "C:\LPA_Data", then the reference trace is set to "C:\LPA_Data\myRef". The software is also configured to use this reference (rather than the default parameter file) to evaluate traces.

SYSTem:SaVeLightPathtrace

Usage: SYST:SVLP {*deviceName*}

Description: Saves the current LightPath trace.

The *deviceName* parameter specified a new subdirectory in the Base Folder where the LightPath files should be saved. (The name of the base folder can be obtained by using the CONF:CFG? query.)

Response: None.

Example: SYST:SVLP device2

Saves the LightPath files to the directory "[Base folder]\device2".

If the base folder is “C:\LPA_Data”, then the files are saved to “C:\LPA_Data\ device2”.

6

Chapter 7

Controlling the OBR Remotely

This chapter provides information about controlling the Optical Backscatter Reflectometer remotely, using GPIB or TCP/IP commands. This section assumes that the user already has some familiarity with either GPIB or TCP/IP. For detailed information about GPIB, see IEEE 488.2 standards documents; for information about TCP/IP, see the IEEE 802 standards documents.

Nearly all functions that can be performed using the graphical interface of the control software can also be performed remotely. This includes setting scan parameters, performing measurements, filtering data, loading and saving data files, as well as receiving data over the remote interface. However, continuous mode is not available with remote operation.

Note: The x-axis and y-axis measurement data may be retrieved using the remote commands. However, it can take a long time to transfer the maximum number of points using the re-mote commands. It is recommended that the number of decimated points be set to 65536 or fewer when using the FETC:MEAS? and FETC:XAXI? commands. For processing larger amounts of data, it is preferable to save files using the SYST:SAVE and SYST:SAVT commands, or to use the Software Development Kit.

For higher speed remote operation, TCP/IP is recommended over GPIB.

Prerequisites for Remote Control Setup

1. Be familiar with the use of GPIB or TCP/IP commands and the OBR control software before attempting to control the OBR remotely.
2. Network cabling must comply with IEEE 488.2 requirements for GPIB operation, or with IEEE 802 requirements for TCP/IP operation.
3. Some OBR functions require several minutes to complete. Adjust GPIB or TCP/IP time-outs for your application accordingly.
4. Each device in the GPIB network must have a unique GPIB address, typically from 1 to 30. The network controller is typically assigned an

address of 0.

5 Be aware of the IP address of the OBR PC in order to use TCP/IP remote control.

Remote Control Setup Configuration

The remote interface type, board address and port number can be configured using the OBR menu selection **Options > Remote Interface Setup**. The following dialog box appears:

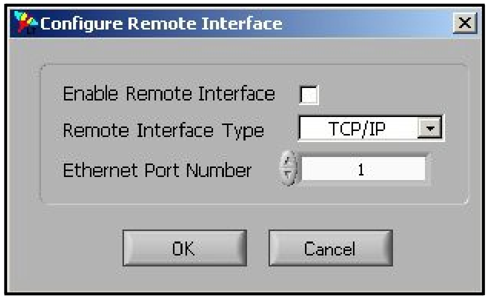


Figure 7-1. The remote interface setup dialog box.

If **Enable Remote Interface** is checked, it is on. The pull-down menu allows the user to select either GPIB or TCP/IP remote interface. TCP/IP is the default interface. The second field is used to set either the GPIB address or the ethernet port number. By default, both the GPIB address and the ethernet port number are set to “1”.

The GPIB board name is set to “GPIB0” by default.

Remotely Connecting to the OBR

A remote client can be written in any language that can send TCP/IP packets or can communicate over a GPIB connection. The remote client should connect to the selected port on the target (or the correct address on the GPIB network) and then send remote commands to the server.

The OBR software includes two example remote clients (one for TCP/IP and another for GPIB) with LabVIEW source code. Shortcuts for these should appear in the Start menu under Start, All Programs, Luna Technologies, OBR.

The LabVIEW source code for both is included in the folder C:\Program Files\Luna Technologies\OBR\Remote Control Example Code. This folder also includes example C++ code to remotely connect to the OBR.

Remote Control Commands for the OBR

This section gives a description of every remote control command available with the OBR control software. The commands are organized by function. For an alphabetical listing of each command, see Table 7-1, “Alphabetical Summary of GPIB and TCP/IP Commands,” on page 163.

Each of the commands listed below may be used for either GPIB or TCP/IP interface. The OBR control software accepts all mandatory IEEE 488.2 commands for GPIB, but only responds to the commands described in this section. The OBR does not accept TCP/IP commands that are not listed in this document.

Important The OBR control software does not support multiple commands on a line, separated by semicolons. Enter each command on a separate line.

IEEE 488.2 defines commands as being either *sequential* or *overlapped*. Sequential commands cause the instrument to ignore other remote control commands until each command has completed. Overlapped commands let the device respond to incoming commands before pending commands completely execute. The OBR processes only sequential commands.

All commands are case-sensitive, and must be entered exactly as they appear in this chapter.

Examples of how to use these commands with Visual Basic® code are given under “Example Visual Basic Code” on page 155.

Remote control commands are classified by types:

- Standard Commands
- System Control Commands
- Configuration Commands
- Data Capture and Retrieval Commands

Standard Commands

These are mandatory commands required by IEEE 488.2. For consistency, they are also accepted by the OBR when operating with TCP/IP. These commands are generally not necessary for performing measurements with the OBR. For more information about these commands, see the IEEE 488.2 standards documents.

*QUIT

Usage: *QUIT

Description: Ends a remote session, allowing the OBR to go back to local control mode.

Response: None.

*CLS

Usage: *CLS
Description: Clears the status register.
Response: None.

*ESE

Usage: *ESE {*n*}
Description: Sets the value (0–255) of the Status Enable register.
Response: None.

*ESE?

Usage: *ESE?
Description: Retrieves the current value (0–255) of the Status Enable register.
Response: Returns a number ranging from 0 to 255.

*ESR?

Usage: *ESR?
Description: Retrieves the value of the Event Status register.
Response: Returns a number ranging from 0 to 255.

*IDN?

Usage: *IDN?
Description: Retrieves the OBR's identification string.
Response: Returns a string identifying the model, manufacturer, and firmware level for the device.

*OPC

Usage: *OPC {0|1}
Description: Enables (1) or disables (0) the "operation complete" event notification.
Response: None.

*OPC?

Usage: *OPC?

Description: Queries the OBR to determine if the operation is complete.

Response: Returns "1" if the previous operation has been completed; "0" if the previous operation is still processing.

*RST

Usage: *RST

Description: Instructs the OBR to reset all parameters to the power-on defaults.

Response: None.

*SRE

Usage: *SRE {*n*}

Description: Sets the value (0–255) of the Service Request Enable register.

Response: None.

*SRE?

Usage: *SRE?

Description: Retrieves the current value of the Service Request Enable register.

Response: Returns the value (0–255) of the Service Request Enable register.

*STB?

Usage: *STB?

Description: Retrieves the value of the Status Byte register.

Response: Returns the value (0–255) of the Status Byte register.

*WAI

Usage: *WAI

Description: Prevents the OBR from executing any further commands or queries until all pending operations have been completed.

Response: None.

*TST?

Usage: *TST?

Description: Performs a self-test query.

Response: None.

System Level Commands

SCAN

Usage: SCAN

Description: Tells the OBR to execute an optical **Scan** based on the configured system parameters. Depending on the wavelength range (CONF:RANG) setting and **Scan Rate** (CONF:RATE), this command may take up to several minutes to complete.

Response: None.

Note: It is advisable to use the *OPC? query until it returns a “1,” to verify that the **Scan** has been completed.

It is also advisable to use the SYST:ERR? query after each SCAN command and before attempting to retrieve the data with FETC queries. This will reveal any errors that occurred during the **Scan**.

SYSTem:SPOTscan

Usage: SYST:SPOT {*center, centerUnits*}

Description: Tells the OBR to execute an optical **Spot Scan** based on the configured system parameters. A **Spot Scan** is performed over the same wavelength range (CONF:RANG) that would be used for a regular **Scan** (triggered by the SCAN command), but only a portion of the data is returned. The data returned is centered around the x-axis location “*center*,” in units “*centerUnits*.” Values for “*centerUnits*” are: 0 for time (ns), 1 for length (m), 2 for length (ft), 3 for inches (in), or 4 for millimeters (mm).

Response: None.

Example: SYST:SPOT 1.5, 1

This command performs a spot scan centered around 1.5 m.

SYSTem:ON?

Usage: SYST:ON?

Description: Queries whether the OBR is on.

Response: Returns "1" if the system is on, "0" if it is off.

SYSTem:WARM?

Usage: SYST:WARM?

Description: Queries if the laser is at operating temperature.

Response: Returns the digit “1” if the laser is at operating temperature, or “0” if it is not at operating temperature.

SYSTem:WarmupTIMeremaining?

Usage: SYST:WTIM?

Description: Retrieves the time remaining on the system one hour warm-up timer.

Response: Returns the current warm-up time left in minutes.

If the OBR instrument and PC have warmed-up for the specified hour, this command will return zero, “0”, meaning no warm-up time is left.

Note: It is always recommended to query the warm-up timer before calibrating and taking measurements. The OBR must be at a stable temperature in order to consistently perform accurate measurements according to published specifications.

SYSTem:VERsion?

Usage: SYST:VER?

Description: Queries the software version.

Response: Returns a string containing the OBR software version.

Example: 2.0.1

SYSTem:LASEr

Usage: SYST:LASE {0|1}

Description: Turns the laser on (1) or off (0).

Response: None.

SYSTem:LASEr?

Usage: SYST:LASE?

Description: Queries the laser state.

Response: Returns “1” if the laser is on, or “0” if the laser is off.

SYSTem:ReaDY?

Usage: SYST:RDY?

Description: Queries if the OBR is ready to **Scan**.

Response: Returns “1” if the OBR is ready to **Scan**, or “0” if it is not.

SYSTem:ERRor?

Usage: SYST:ERR?

Description: Retrieves the error code for the most recent remote operation.

Response: Returns a numeric error code. A code of 0 indicates no error; *i.e.* the last command or query completed successfully. Any non-zero number indicates that an error has occurred. A description of the error may be retrieved with the query SYST:ERRD?

SYSTem:ERRorDescription?

Usage: SYST:ERRD?

Description: Retrieves the detailed error description for the most recent remote operation.

Response: Retrieves a string explaining the results of the most recent operation. The total length of the error message will be less than 512 bytes. Two examples of error messages are:

Examples: Group index set to 1.5

Not a valid trace: W

Missing parameter: <center wavelength>

SYSTem:ALIGn

Usage: SYST:ALIG

Description: **Aligns** the optics.

Response: None.

Notes: This process may take several minutes. Adjust the time-outs for your application accordingly.

After a successful alignment, the system will automatically perform calibration.

Poll for *OPC? to determine when this operation has completed.

SYSTem:ALIGn?

Usage: SYST:ALIG?

Description: Queries the OBR if the optics are aligned.

Response: Returns “1” if the optics are aligned, or “0” if they are not.

Note: This command is only valid immediately following a system calibration (SYST:CAL).

SYSTem:CALibration

Usage: SYST:CAL

Description: **Calibrates** the system.

A gold reflector must be connected to the OBR before issuing this command.

Response: None.

Notes: This process may take several minutes to complete, so adjust application time-outs accordingly.

Poll for *OPC? to see whether the operation is completed.

SYSTem:CALibration?

Usage: SYST:CAL?

Description: Queries the system calibration status.

Response: Returns “1” if the system is in calibration or “0” if it is not.

Note: The validity of calibration is checked with every scan. If it is determined that the calibration is no longer valid, then this status switches to “0.” In this case, the user may either recalibrate by using the SYST:CAL command described above, or reload the previous calibration using the SYST:RLDC command below.

SYSTem:WCLF?

Usage: SYST:WCLF?

Description: Queries whether the wavelength calibration failed during the previous scan. It is analogous to the “Wavelength Cal Failed” warning light that appears in the OBR software.

Response: Returns 1 if the wavelength calibration failed, or 0 if it did not. Note that this only applies to scans started remotely (using the SCAN or SYST:SPOT commands), not scans that were performed using the local Scan button.

Example: SYST:WCLF?

This query returns the value 1 or 0, depending on whether the wavelength calibration failed or not.

SYSTem:ReLoaDCalibration

Usage: SYST:RLDC

Description: Reloads into memory the calibration file set by SYST:CALF (described below).

Response: None.

Note: The user may send this command if SYST:CAL? returns a “0,” indicating that the calibration failed. Alternately, the user may recalibrate using the or SYST:CAL command described above.

SYSTem:CALibrationFile

Usage: SYST:CALF {0, filename}

Description: Sets the name of the calibration file. If the filename is not specified, this command sets calibration file to the default filename, obrCal_refl.

Because this command is used for other Luna systems, the user must specify zero (0) with this command for a reflection calibration.

Response: None.

Example: SYST:CALF 0, c_band

This instructs the OBR to use the "c_band" calibration file.

SYST:CALF 0

This instructs the OBR to use the default calibration file, obrCal_refl.

SYSTem:CALibrationFile?

Usage: SYST:CALF? 0

Description: Retrieves the name of the calibration file.

Because this command is used for other Luna systems, the user must specify zero (0) with this command to retrieve the calibration filename.

Response: Returns the name of the calibration file currently in use.

SYST:SAT?

Usage: SYST:SAT?

Description: Queries whether the detectors were saturated during the previous scan. It is analogous to the “Detectors saturated, reduce gain” warning light that appears in the OBR software.

Response: Returns 1 if the detectors were saturated, or 0 if the detectors were not saturated. Note that this only applies to scans started remotely (using the SCAN or SYST:SPOT commands), not scans that were performed using the local mode Scan button.

Example: SYST:SAT?

This query returns the value 1 or 0, depending on whether the detectors were saturated or not.

SYSTem:LOAD

Usage: SYST:LOAD {*"filename.obr"*, *trace*}

Description: Loads the external file specified in quotes as a source of data reference for the measurement.

If the file format is not correct, an error flag will be set. The cause of the error can be determined by using the SYST:ERRD? query.

Response: None.

Example: SYST:LOAD “c:\SavedFiles\test.obr”, C

Loads the data contained in the file “test.obr” into *Trace C*.

Notes: The entire file path must be in quotes, and the file type ".obr" must be specified. The *trace* is specified as a single letter: A, B, C, D or E. If no *trace* is specified, the specified file will be loaded into *Trace A*.

SYSTem:SAVE

Usage: SYST:SAVE {*"filename.obr", trace*}

Description: Saves the specified *trace* data as a binary file using the specified filename. The file name must be in quotes, and the file type ".obr" must be specified. If no *trace* (A-E) is specified, the data in *Trace A* will be saved.

Response: None.

Note: An error flag will be set if no data is available to save. The cause of error can be determined by using the SYST:ERRD? or SYST:ERR? query.

Example: SYST:SAVE "C:\SavedFiles\TR.obr", D

Saves the data from *Trace D* into the file "TR.obr."

SYST:SaveSEGment

Usage: SYST:SSEG {*"filename", trace*}

Description: Saves as a binary file the segment of the trace defined by the **Integration Area** [or, in purchased **Sensing Mode** (see page 48), the **Sensing Area**]. This is analogous to selecting "Save Lower Graph Segment" when saving a file from the main software.

Response: None.

Example: CONF:XUNI 1

INTC 3

INTW 1.5

SYST:SSEG "c:\myfile.obr", A

Defines an **Integration Area** (or **Sensing Area**) of 1.5 meters centered at 3 meters, and saves that data to a file named C:\myfile.obr.

SYSTem:SAVText

Usage: SYST:SAVT {*"filename.txt", trace, domain, graphType, units, spatialResolution*}

Description: Saves the specified *trace* (A, B, C, D or E) data as a spreadsheet or text file using the specified filename. The file name must be in quotes, with the file type “.txt” inside the quotes as well. If no *trace* is specified, *Trace A* will be saved.

Domain can be set to 0 for time domain, or 1 for frequency domain.

GraphType can take values from 0 to 8, depending on the *domain* specified, as shown in the table on page 145. However, parameters 5 through 8 are only available when purchased as a separate option.

Units for the time domain can be set to 0 for time (ns), 1 for length (m), 2 for length (ft), 3 for inches (in), 4 for millimeters (mm).

Units for the frequency domain can be set to 0 for wavelength (nm), 1 for frequency (GHz), or 2 for frequency (THz).

SpatialResolution sets the spatial **Resolution Bandwidth** (mm).

Response: None.

Example: SYST:SAVT “C:\SavedFiles\measData.txt”, E

Saves the data from Matrix E into the file “measData.txt.”

SYSTem:COPY

Usage: SYST:COPY {*source*, *destination*}

Description: Copies data from the *source* trace to the *destination* trace.

Response: None.

Example: SYST:COPY A, C

Copies the data from Trace A to Trace C.

SYSTem:ACQuired?

Usage: SYST:ACQ?

Description: Queries whether data has been acquired.

Response: Returns "1" if data has been acquired by the OBR, "0" if not.

SYSTem:GET?

Usage: SYST:GET? {*trace*}

Description: Queries whether data is loaded in the specified *trace* (A-E). If no *trace* is specified, *Trace A* will be assumed.

Response: Returns "1" if data is loaded into the specified *trace*, "0" if data is not loaded into that *trace*.

SYST:LAST?

Usage: SYST:LAST?

Description: Queries the last remote command or query processed by the device. This query can be used to determine whether a command was received and processed.

Response: Returns the name of the last remote command or query processed by the device.

Example: CONF:INTW 1.5

SYST:LAST?

This query returns "CONF:INTW". Note that SYST:LAST? only returns the name of the last command and does not report any parameters included with the command.

Configuration Commands

CONFigure:CenterWaveLength

Usage: CONF:CWL {*centerWavelength*}

Description: Sets the **Center Wavelength** (nm). The wavelength parameter must be within the operating range of the instrument.

Response: None.

Notes: Setting the center wavelength will cause the start and end wavelengths to be adjusted to match the new center wavelength and the wavelength range set using the CONF:RANG command.

If the center wavelength and **Scan Range** settings for a measurement fall outside the most recent calibration, the wavelength settings will be coerced to fit within the most recent calibration.

CONFigure:CenterWaveLength?

Usage: CONF:CWL?

Description: Retrieves the current **Center Wavelength** in nanometers.

Response: Returns the current **Center Wavelength** in nanometers.

CONFigure:STARt

Usage: CONF:STAR {*startWavelength*}

Description: Sets the start wavelength for the scan in nanometers. The wavelength parameter must be within the operating range of the instrument.

If the start wavelength falls outside the limits of the instrument, the command is accepted, but the start wavelength will be coerced to the nearest wavelength within the OBR's limits using the current setting of **Wavelength Range**.

Response: None.

Notes: Setting the start wavelength will cause the center and end wavelengths to be adjusted to match the new start wavelength and the wavelength range set using the CONF:RANG command.

Example: CONF:STAR 1525.0

This command sets the starting wavelength to 1525.0 nm.

CONFigure:STARt?

Usage: CONF:STAR?

Description: Retrieves the current start wavelength in nanometers.

Response: Returns the current start wavelength in nanometers.

Example: CONF:STAR?

This query returns a message in the form “1525.00.”

CONFigure:END?

Usage: CONF:END?

Description: Queries the OBR for the current ending wavelength.

Response: Returns the current ending wavelength in nanometers.

Example: CONF:END?

This query returns a message in the form “1590.00” nm.

CONFigure:RANGe

Usage: CONF:RANG {*scanRange*}

Description: Sets the **Scan Range** in nanometers. The OBR only allows scan ranges that have a number of data points equal to a power of two, so the actual value of the **Scan Range** will be set to the valid value closest to *scanRange*.

Response: None.

Notes: If the center wavelength and scan range settings for a measurement fall outside the most recent calibration, the wavelength settings will be coerced to fit within the most recent calibration.

Examples: CONF:RANG 5.0 sets the **Scan Range** to the valid range closest to 5.0 nm.

CONFigure:RANGe?

Usage: CONF:RANG?

Description: Queries the OBR for the current **Scan Range** in nanometers.

Response: Returns the current **Scan Range** in nanometers, in the form "20.0."

Examples: "CONF:RANG?" returns the **Scan Range** in nanometers.

CONFigure:INTegrationWidth

Usage: CONF:INTW {*integrationWidth*}

Description: Sets the OBR **Integration Width** in the units set by CONF:XUNI (page 139).

[In optional **Sensing** mode (page 48), the CONF:INTW command sets the **Sensing Range**, also in the units set by CONF:XUNI. Alternatively, you may use the CONF:SRAN command (see below) to set the **Sensing Range**.]

Response: None.

Notes: The **Integration Width** (or **Sensing Range**), along with the **Integration** (or **Sensing**) start (CONF:INTS) or center (CONF:INTC) set commands, defines the area that will be used for data capture and retrieval commands such as FETC:MEAS. All frequency domain values are based on this **Integration Width** (or **Sensing Range**) and start or center. Setting the **Integration Width** (or **Sensing Range**) to 0 indicates that the entire measurement area should be used for such commands.

Setting the **Integration Width** (or **Sensing Range**) will cause the **Integration** (or **Sensing**) center to be adjusted to match the new **Integration Width** (or **Sensing Range**) and the **Integration** (or **Sensing**) start set using the CONF:INTS command.

CONFigure:INTegrationWidth?

Usage: CONF:INTW?

Description: Retrieves the OBR **Integration Width** in the units set by CONF:XUNI (page 139).

[In optional **Sensing** mode (page 48), this returns the **Sensing Range**, also in the units set by CONF:XUNI. Alternatively, you may use the CONF:SRAN? command (see below) to retrieve the **Sensing Range**.]

Response: Returns the OBR **Integration Width** (or **Sensing Range**) in meters.

CONFigure:DECImation

Usage: CONF:DECI { number of decimated points }

Description: Sets the number of decimated points

Response: None.

Notes: This command controls the number of points that will be returned by the FETC:XAXI? and FETC:MEAS? commands, as well as the number of points written to the text file using the SYST:SAVT command. It does not affect the amount of data written to the binary file using SYST:SAVE; the binary file always contains the full measurement data.

Example: CONF:DECI 4096

This command sets the number of decimated points to 4096.

CONFigure:DECImation?

Usage: CONF:DECI?

Description: Retrieves the number of decimated points

Response: Returns the number of decimated points

CONFigure:DistanceRANge

Usage: CONF:DRAN {*distanceRange*}

Description: Sets the OBR **Distance Range** to **Normal** (0) or **Extended**

(1) range (page 28).

Response: None.

CONFigure:DistanceRANge?

Usage: CONF:DRAN?

Description: Retrieves the OBR **Distance Range** (page 28).

Response: Returns the **Distance Range**, either zero (0) in the **Normal Range** or one (1) in the **Extended Range**.

CONFigure:DeviceUnderTestLength

Usage: CONF:DUTL {*length*}

Description: Sets the DUT length to the value specified in meters for **Extended Range** mode. This command has no effect on **Normal Distance Range** scans.

Response: None.

Example: "CONF:DUTL 4.3125" sets the length of the DUT to 4.3125 m.

CONFigure:DeviceUnderTestLength?

Usage: CONF:DUTL?

Description: Queries the current DUT length (in meters) for **Extended Range** mode.

Response: Returns the current DUT length in meters.

CONFigure:SensingRANge

Usage: CONF:SRAN {*sensingRange*}

Description: In optional **Sensing** mode (page 48), sets the OBR **Sensing Range** in the units set by CONF:XUNI (page 139).

[Note that CONF:INTW will perform the same function in **Sensing** mode.]

Response: None.

Notes: The **Sensing Range**, along with the **Sensing** start (CONF:INTS) or center (CONF:INTC) set commands, defines the area that will be used for data capture and retrieval commands such as FETC:MEAS. All frequency domain values are based on this **Sensing Range** and start or center. Setting the **Sensing Range** to 0 indicates that the entire measurement area should be used for such commands.

Setting the **Sensing Range** will cause the **Sensing** center to be adjusted to match the new **Sensing Range** and the **Sensing** start set using the CONF:INTS command.

CONFigure:SensingRANge?

Usage: CONF:SRAN?

Description: Retrieves the OBR **Sensing Range** in the units set by CONF:XUNI (page 139).

[The user may also use the **CONF:INTW?** command to perform the same function.]

Response: Returns the OBR **Sensing Range** in meters.

CONFigure:INTegrationStart

Usage: CONF:INTS {*integrationStart*}

Description: Sets the OBR **Integration Area** start in the units set by CONF:XUNI (page 139).

[In **Sensing** mode, this sets the **Sensing Area** start, also in the units set by CONF:XUNI.]

Response: None.

Note: Setting the **Integration** (or **Sensing**) start will cause the **Integration** (or **Sensing**) center to be adjusted to match the new **Integration** (or **Sensing**) start and the **Integration Width** (or **Sensing Range**) set using the CONF:INTW command.

CONFigure:INTegrationStart?

Usage: CONF:INTS?

Description: Retrieves the OBR **Integration** (or **Sensing**) **Area** start in the units set by CONF:XUNI (page 139).

Response: Returns the OBR **Integration** (or **Sensing**) **Area** start.

CONFigure:INTegrationCenter

Usage: CONF:INTC {*integrationCenter*}

Description: Sets the OBR **Integration** (or **Sensing**) **Area** center in the units set by CONF:XUNI (page 139).

Response: None.

Note: Setting the **Integration** (or **Sensing**) **Area** center will cause the **Integration** (or **Sensing**) **Area** start to be adjusted to match the new **Integration** (or **Sensing**) **Area** center and the **Integration Width** (or **Sensing Range**) set using the CONF:INTW command.

CONFigure:INTegrationCenter?

Usage: CONF:INTC?

Description: Retrieves the OBR **Integration** (or **Sensing**) **Area** center in the units set by CONF:XUNI (page 139).

Response: Returns the OBR **Integration** (or **Sensing**) **Area** center in the units set by CONF:XUNI.

CONFigure:SENSing

Usage: CONF:SENS { *0 ot 1*}

Description: Turns sensing mode On (1) or Off (1)

Response: None.

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Note: Turning sensing mode on disables rolloff corrections. It does not change the laser sweep speed or disable the frequency window filter, both of which are done when entering Sensing Mode in the OBR GUI. These actions can be performed separately by using the CONF:RATE and CONF:FWIN commands.

CONFigure:SENSing?

Usage: CONF:SENS?

Description: Retrieves sensing mode setting.

Response: Returns 1 if sensing mode is enabled, or 0 if it is disabled.

CONFigure:GaugeLENngth

Usage: CONF:GLEN {*gaugeLength*}

Description:	Sets the gauge length in cm. This is the new name for CONF:SRES {*sensingResolution*}. The CONF:SRES command is still supported, but may be discontinued in the future.
Response:	None
Examples:	CONF:GLEN 1.5
	Sets the gauge length to 1.5 cm.

CONFigure:GaugeLENngth?

Usage:	CONF:GLEN?
Description:	Queries the gauge length. This is the new name for CONF:SRES? {*sensingResolution*}. The CONF:SRES? query will continue to be supported, but may be discontinued in the future.
Response:	Returns the gauge length in cm.
Example:	CONF:GLEN?
	This query returns the gauge length in cm.

CONFigure:SensorSPAcing

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Usage:	CONF:SSPA
Description:	Sets the **Sensor Spacing** in cm. The sensor spacing was previously tied to the **Sensing Resolution** value, and both were set by the CONF:SRES command. It is now a separate value with its own command.
Response:	None.
Example:	CONF:SSPA 2.0
	Sets the **Sensor Spacing** to 2.0 cm.

CONFigure:SensorSPAcing?

Usage:	CONF:SSPA?
Description:	Queries the **Sensor Spacing**.
Response:	Returns the **Sensor Spacing** in cm.
Example:	CONF:SSPA?
	This query returns the **sensor spacing** in cm.

CONFigure:SensingRESolution and CONF:SRES?

Note: Being replaced by the command CONF:GLEN and CONF:SSPA (above).

CONFigure:XaxisUNIts

Usage: CONF:XUNI {units}

Description: Sets the X-axis units being used to specify the **Integration** (or **Sensing**) **Area**. These are the units that will be used by the CONF:INTW, CONF:INTS, and CONF:INTC commands and queries to report or set the **Integration Width** (or **Sensing Range**), start, and center. The units parameter must have one of the following values:

0 : nanoseconds

1 : meters

2 : feet

3 : inches

4 : millimeters

Response: None

Example: CONF:XUNI 0

CONF:INTW?

Response: 15.010384

The CONF:XUNI command sets the x-axis units to nanoseconds. This means that the CONF:INTW? response should be interpreted as 15.01 nanoseconds, and that any CONF:INTW, CONF:INTS, or CONF:INTC commands should specify their units in nanoseconds.

CONFigure:XaxisUNIts?

Usage: CONF:XUNI?

Description: Queries the X-axis units being used to specify the **Integration Width** (or **Sensing Range**). These are the units that will be used by the CONF:INTW, CONF:INTS, and CONF:INTC commands and queries to report or set the **Integration** (or **Sensing**) width, start and center.

Response: Returns a number indicating the x-axis units used to define the **Integration** (or **Sensing**) **Area**. The possible responses are:

0 : nanoseconds

1 : meters

2 : feet

3 : inches

4 : millimeters

Example: CONF:XUNI?

Response: 1

CONF:INTW?

Response: 1.5

The CONF:XUNI? response of 1 means that x-axis units are meters (See “CONFigure:XaxisUNIts?” on page 139). This means that the CONF:INTW? response should be interpreted as 1.5 meters, and that any CONF:INTW, CONF:INTS, or CONF:INTC commands should specify their units in meters.

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CONFigure:RATE

Usage: CONF:RATE {*sweepRate*}

Description: Sets the laser sweep rate in nm/sec, allowing for **Fast Scan Mode**. The default sweep rate is set by the device EEPROM and is usually 10 nm/sec. The rate can be set as high as 200 nm/sec. If the user-specified *sweepRate* is higher or lower than allowed, CONF:RATE will set the sweep rate to the closest possible value. The CONF:RATE? query can be used to retrieve the actual rate that was set. Higher sweep rates allow faster measurements, but higher sweep rates may result in less accurate measurements for a device with a high return loss.

Response: None

Example: CONF:RATE 100

This command sets the laser sweep rate to 100 nm/sec.

CONFigure:RATE?

Usage: CONF:RATE?

Description: Queries the laser sweep rate.
Response: Returns the current laser sweep rate in nm/sec.
Example: CONF:RATE?
This query returns the laser sweep rate in nm/sec.

CONFigure:GRouP

Usage: CONF:GRP {*groupIndex*}
Description: Sets the OBR **Group Index**.
Response: None.

CONFigure:GRouP?

Usage: CONF:GRP?
Description: Retrieves the OBR **Group Index**.
Response: Returns the OBR **Group Index**.

CONFigure:RESolutionGhz?

Usage: CONF:RESG?
Description: Retrieves the **Resolution Bandwidth** in GHz.
Response: Returns the **Resolution Bandwidth** in GHz.

CONFigure:RESolutionPicometers?

Usage: CONF:RESP?
Description: Retrieves the **Resolution Bandwidth** in picometers.
Response: Returns the **Resolution Bandwidth** in picometers.

CONFigure:SpatialResolutionBandWidth

Usage: CONF:SRBW {*spatialResolution*} Description:
Sets the spatial **Resolution Bandwidth** (mm).
Response: None.

CONFigure:SpatialResolutionBandWidth?

Usage: CONF:SRBW?
Description: Retrieves the spatial **Resolution Bandwidth** in millimeters.
Response: Returns the spatial **Resolution Bandwidth** in millimeters.

CONFigure:SpatialResolutionFilterWidth

Usage: CONF:SRFW {*filterWidth*}

Description: Sets the **Spatial Resolution Filter** width (ns).

Response: None.

CONFigure:SpatialResolutionFilterWidth?

Usage: CONF:SRFW?

Description: Retrieves the **Spatial Resolution Filter** width in nanoseconds.

Response: Returns the **Spatial Resolution Filter** width in nanoseconds.

CONFigure:GAIN

Usage: CONF:GAIN {*gain*}

Description: Sets the gain vector index.

Response: None.

CONFigure:GAIN?

Usage: CONF:GAIN?

Description: Retrieves the gain vector index.

Response: Returns the gain vector index.

CONFigure:SpatialresolutionFILter

Usage: CONF:SFIL {0|1}

Description: Sets the **Spatial Resolution Filter**, or smoothing filter, flag on (1), or off (0).

Response: None.

Note: Data can be filtered after a scan.

CONFigure:SpatialresolutionFILter?

Usage: CONF:SFIL?

Description: Retrieves the **Spatial Resolution Filter** flag.

Response: Returns “1” if the **Spatial Resolution Filter** flag is on, “0” if it is off.

CONFigure:FrequencydomainWINdow

Usage: CONF:FWIN {0|1}

Description: Sets the frequency domain window flag, indicating whether or not a frequency domain window is applied to new measurements. A value of 0 (do not apply window) or 1 (apply window) must be specified as a parameter.

Response: None

Example: CONF:FWIN 1

This command causes the frequency domain filter to be applied to all new measurement scans.

CONFigure:FrequencydomainWINdow?

Usage: CONF:FWIN?

Description: Queries the frequency domain window flag, indicating whether or not a frequency domain window is applied to new measurement scans.

Response: Returns a value of 0 (window is not applied) or 1 (window is applied).

Example: CONF:FWIN?

This query returns 0 or 1.

CONFigure:COEFficients

Usage: CONF:COEF {trace, t0, t1, t2, t3, t4, s0, s1, s2, s3, s4}

Description: Sets the temperature and strain coefficients used to generate the Temperature Change and Strain curves. Either a trace (“A” through “E”) or the word (“DEFAULT”) must be specified as the first parameter. Specifying a trace sets the coefficients for that trace. Specifying “DEFAULT” sets the default coefficients that will be used for new measurements.

Response: None

Example: CONF:COEF DEFAULT, 0, -0.75, 0.05, 0.01, 0.00, -0.1, -0.2, -0.3, -0.4, -0.5

Sets the default temperature coefficients to {0, -0.75, 0.05, 0.01, 0.00}, and the default strain coefficients to {-0.1, -0.2, -0.3, -0.4, -0.5}.

CONFigure:COEFficients?

Usage: CONF:COEF? {trace, or “DEFAULT”}

Description: Queries the temperature and strain coefficients used to generate the Temperature Change and Strain curves. Either a trace (“A” through “E”) or the word (“DEFAULT”) must be specified as a parameter.

Response: Returns the coefficients defined for the specified trace, or the default coefficients that will be used for new measurements. There are five temperature coefficients labeled t0 through t4, and five strain coefficients labeled s0 through s4. All values are prefaced by their label and separated by tab characters.

Example: CONF:COEF? A

This query returns a message in the form

t0: 0.000000	t1: -0.801388	t2: 0.000000
t3: 0.000000	t4: 0.000000	s0: 0.000000
s1: -6.668000	s2: 0.000000	s3: 0.000000
s4: 0.000000		

Data Capture and Retrieval Commands

FETCh:FREQuency?

Usage: FETC:FREQ? {*trace*}

Description: Queries the OBR for the starting frequency and the increment size, both in units of GHz.

Response: Returns the starting frequency and increment size, separated by a comma.

If no *trace* is specified, the values for *Trace A* will be returned. If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

Example: FETC:FREQ? B

This query returns a message in the form “193414.488699,0.001214,” meaning the starting frequency for Trace B is 193414.488699 GHz and the frequency increment size/sample spacing is 0.001214 GHz.

FETCh:FSIZe?

Usage: FETC:FSIZ? {*trace*, *domain*, *graphType*, *decimate*} *Trace* is specified as a single letter: A, B, C, D or E. *Domain* can be set to 0 for time domain, or 1 for frequency domain.

graphType	Graph/Parameter Name
Time Domain (*domain* = 0) Values	
0	Amplitude
1	Linear Amplitude
2	Polarization States
3	Phase Derivative
4	Amplitude (dB)
5	Spectral Shift (only on some units)
6	Temporal Shift (only on some units)
7	Strain (only on some units)
8	Temporal Shift (only on some units)
Frequency Domain (*domain* = 1) Values	
0	Return Loss
1	Linear Amplitude
2	Polarization States
3	Group Delay

GraphType can take values from 0 to 8, as shown above. However, parameters 5 through 8 are only available when purchased as a separate option. The assignment of *graphType* depends on which *domain* is specified. (Note that this list of values for *graphType* may be retrieved using the FETC:GNAM? query, below.)

Decimate can be set to 1 to use decimation, or 0 to return all points.

Description: Retrieves the size of the data arrays; *i.e.* the number of data samples to expect from the FETC:MEAS? queries.

All parameters must be specified.

This query should be called before performing the FETC:MEAS? command if the controller program needs to pre-allocate space for the data.

Example: FETC:FSIZ? A, 0, 0, 1

This command returns the data array size of *Trace A's* time domain amplitude data, with data decimation on.

Response: The response is an integer indicating the number of data samples to expect from the FETC:MEAS? queries.

If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data."

FETCh:GraphNAMe?

Usage: FETC:GNAM?

Description: Retrieves the available graph names for all numeric values of *graphType* for both time and frequency domain. This allows the user to see what curve is associated with what *graphType* value when calling FETC:MEAS? and other commands that use the *graphType* parameter.

Response: The query returns the list of values of *graphType* for each domain, as shown above under FETC:FSIZ?, beginning on page 145.

FETCh:GraphSTRings?

Usage: FETC:GSTR? {*domain*, *graphType*, *xUnits*}

Description: Retrieves the graph title or name, the Y-axis label, and the X-axis label for the specified *domain*, *graphType*, and *xUnits*.

Domain can be set to 0 for time domain, or 1 for frequency domain.

GraphType can take values from 0 to 4 or 8, as shown in the table beginning on page 145. The assignment of *graphType* depends on which *domain* is specified.

xUnits for the time domain can be set to 0 for time (ns), 1 for length (m), 2 for length (ft), 3 for inches (in), or 4 for length (mm).

	xUnits for the frequency domain can be set to 0 for wavelength (nm), 1 for frequency (GHz), or 2 for frequency (THz).
Response:	Returns the curve name or title on the first line, Y-axis label on the second line, and the X-axis label on the third line. The returned strings can be used to properly label a graph plotted with values obtained from the FETC:MEAS? and FETC:XAXI? queries.
Examples:	FETC:GSTR? 0, 0, 1
	Returns graph title, Y-axis label, and X-axis label in the form:
	Amplitude
	Amplitude (dB/mm)
	Length (m)
	FETC:GSTR? 1, 3, 0
	Returns: Group
	Delay Group
	Delay (ns)
	Wavelength (nm)

FETCh:MEASurement?

Usage:	FETC:MEAS? {*trace, domain, graphType, decimate*}
	Trace is specified as a single letter: A, B, C, D or E.
	Domain can be set to 0 for time domain, or 1 for frequency domain.
	GraphType can take values from 0 to 4 or 8, as shown in the table above. The assignment of *graphType* depends on which *domain* is specified. These values are listed in the table above, beginning on page 145.
	Decimate can be set to 1 to use decimation, or 0 to return all points.
Description:	Retrieves the Y-axis data for the specified parameters. The portion of the data that is returned is determined from the **Integration** (or **Sensing**) **Area** previously specified with the CONF:INTW, CONF:INTS, and CONF:INTC

commands. If the **Integration Width** (or **Sensing Range**) is set to 0, then the Y-axis data is returned for the entire measurement area.

This query is usually preceded by the FETC:FSIZ? query to determine the number of data points that will be returned.

All parameters must be specified.

Response: Returns a series of numbers representing the Y-axis data points for the requested area.

The data are returned as an array with each element in floating point format with ten significant digits and possible exponent field of the form [?]d.ddddddddd[e[?]ddd].

If space needs to be allocated for the receiving buffer, the amount required for each element is 18, including a carriage return as the delimiter.

The number of points is the same as the value obtained by sending the FETC:FSIZ? request with the same parameters. The string "///" is returned after the last data point to indicate that the response is complete.

If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

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Example: FETC:MEAS? C, 1, 3, 1

Retrieves the Y-axis data for *Trace C’s* frequency domain phase derivative data, with decimation on.

-101.101531

-102.912509

-99.7946707

...

-102.621305

-72.7263532

///

FETCh:XAXIs?

Usage: FETC:XAXI? {*trace, domain, units, decimate*}

Trace is specified as a single letter: A, B, C, D or E.

Domain can be set to 0 for time domain, or 1 for frequency domain.

Units for the time domain can be set to 0 for time (ns), 1 for length (m), 2 for length (ft), 3 for length (in), or 4 for length (mm).

Units for the frequency domain can be set to 0 for wavelength (nm), 1 for frequency (GHz), or 2 for frequency (THz).

Decimate can be set to 1 to use decimation, or 0 to return all points.

Description: Retrieves the X-axis data for the specified parameters.

All parameters must be specified.

Response: Returns a series of numbers representing the X-axis data points for the requested area. The number of points is the same as the value obtained by sending the FETC:FSIZ? query with the same parameters. The string "///" is returned after the last data point to indicate that the response is complete.

The data are returned as an array with each element in floating point format with ten significant digits and possible exponent field of the form [?]d.ddddddddd[e[?]ddd].

If space needs to be allocated for the receiving buffer the amount required for each element is 18, including a carriage return as the delimiter.

If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data." The cause of error can be retrieved by using the SYST:ERRD? query.

Example: FETC:XAXI? C, 1, 0, 1

This query returns the frequency domain X-axis data from Trace C, in nanometers, decimated, in the form:

```
1509.97
1509.99
...
1525.01
1525.02
///
```

FETCh:MeasurementDETails?

Usage: FETC:MDET? {*trace*}

Description: Queries the OBR for current measurement **Details** for *trace* specified. The *trace* is specified as a single letter: A, B, C, D or E.

Response: Returns a string of information (shown below) about the specified (A-E) or default (A) *trace*.

If no *trace* is specified, the measurement **Details** for *Trace A* will be returned. If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data." The cause of error can be retrieved by using the SYST:ERRD? query.

Example: FETC:MDET?

This query returns a message in the form:

Trace: A
Starting frequency (GHz): 193414.488699
Frequency increment (GHz): 0.001214
Segment size: 2097152
Starting time (ns): -55.000141
Time increment (ns): 0.000393
Measurement type: 0
Group index: 1.500000
Time stamp: 1/20/2005 16:23:43
Filename: C:\obr data\Jan20_10m.obr
Device descriptor: Network switch

FETCh:RAW?

Usage: FETC:RAW? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the raw S and P data for the specified *trace*.

The portion of the data that is returned is determined from the **Integration Width** (or **Sensing Range**) previously specified with the CONF:INTW, CONF:INTS, and CONF:INTC commands. If the **Integration Width** (or **Sensing Range**) is set to 0, then the data is returned for the entire measurement area.

Response: Returns a series of four tab-separated numbers, each set of numbers representing the S and P values for a single point. The number of points is the same as the value obtained by sending the FETC:RSIZ? request with the same trace parameter.

The values for each point are formatted as:

{S real <tab> S imaginary <tab> P real <tab> P imaginary}

The string "///" is returned after the last data point to indicate that the response is complete.

If no *trace* is specified, the data for *Trace A* will be returned. If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

Example: FETC:RAW? C

Returns the S and P data for *Trace C* in the form:

-6.27743856e+066	-6.27743856e+066	-6.27743856e+066	-6.27743856e+066
-6.27743856e+066	-6.27743856e+066	-6.27743856e+066	-6.27743856e+066
...			
-6.27743856e+066	-6.27743856e+066	-6.27743856e+066	-6.27743856e+066
-6.27743856e+066	-6.27743856e+066	-6.27743856e+066	-6.27743856e+066
///			

FETCh:RawdataSIZe?

Usage: FETC:RSIZ? {*trace*}

Description: Retrieves the size of the raw S and P data for the specified *trace*. This is the number of data points that will be returned by the FETC:RAW? query using the current **Integration Area** [or in purchased **Sensing Mode** (page 48), the **Sensing Area**] as specified by the CONF:INTW, CONF:INTS, and CONF:INTC commands.

Response: Returns the size of the raw S and P data for the specified *trace*.

If no *trace* is specified, the data size for *Trace A* will be returned. If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

FETCh:FrequencydomainDETail?

Usage: FETC:FDET? {*trace, graphType, decimate*}

Trace is specified as a single letter: A, B, C, D or E.

GraphType can take values from 0 to 4, as shown in the table beginning on page 145. Only the frequency domain values of *graphType* are used in this command.

Decimate can be set to 1 to use decimation, or 0 to return all points.

Description: Retrieves additional detail for the frequency domain curves.

Response: Returns integrated insertion loss (dB) for *graphType* = 0, and average delay (ns) for *graphType* = 1 or 2.

FETCh:WaveLength?

Usage: FETC:WL? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the starting wavelength (nm) for the specified *trace*.

Response: Returns the starting wavelength, in nanometers, for the specified *trace*. If no *trace* is specified, the starting wavelength for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data."

FETCh:WaveLengthCenter?

Usage: FETC:WLC? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the center wavelength (nm) for the specified *trace*.

Response: Returns the center wavelength, in nanometers, for the specified trace. If no *trace* is specified, the center wavelength for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data."

FETCh:WaveLengthEnd?

Usage: FETC:WLE? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the ending wavelength (nm) for the specified *trace*.

Response: Returns the ending wavelength, in nanometers, for the specified trace. If no *trace* is specified, the ending wavelength for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data."

FETCh:INTegrationLoss?

Usage: FETC:INTL? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the loss of the current **Integration Area** [or in purchased **Sensing Mode** (page 48), the **Sensing Area**] for the specified *trace*. The **Integration** (or **Sensing**) **Area** is the area previously specified by the CONF:INTW, CONF:INTS, and CONF:INTC commands.

Response: Returns the loss in dB for the current **Integration** (or **Sensing**) **Area** of the specified *trace*. If no *trace* is specified, the loss for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data."

FETCh:TimedomainINCrement?

Usage: FETC:TINC? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the time increment of the **Time Domain Window** X-axis in nanoseconds (ns).

Response: Returns the time increment of the **Time Domain Window** X-axis in nanoseconds. If no *trace* is specified, the time increment for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with "Trace A (B, etc.) contains no data."

Example: FETC:TINC?

This query returns a message in the form "0.000567" ns.

FETCh:TIMeStart?

Usage: FETC:TIMS? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the start time for the specified *trace*.

Response: Returns the start time in nanoseconds for the specified trace. If no *trace* is specified, the start time for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

FETCh:TIMEnd?

Usage: FETC:TIME? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the end time for the specified *trace*.

Response: Returns the end time in nanoseconds for the specified *trace*. If no *trace* is specified, the end time for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

FETCh:LENgthStart?

Usage: FETC:LENS? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the start length for the specified *trace*.

Response: Returns the start length in meters for the specified *trace*. If no *trace* is specified, the start length for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

FETCh:LENgthEnd?

Usage: FETC:LENE? {*trace*}

Trace is specified as a single letter: A, B, C, D or E.

Description: Retrieves the end length for the specified *trace*.

Response: Returns the end length in meters for the specified *trace*. If no *trace* is specified, the end length for *Trace A* is returned. If a successful scan has not been made before this query, the OBR responds with “Trace A (B, etc.) contains no data.”

Alphabetical Command Summaries

The table below provides summaries of GPIB and TCP/IP commands, listed alphabetically by command. For detailed information about each command, see “Remote Control Commands for the OBR” above, beginning on page 120. All commands are given in their truncated form, and are case-sensitive. They must be entered exactly as they appear in this chapter.

Important The OBR control software does not support multiple commands on a line, separated by semicolons. Enter each command on its own separate line.

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

Command	Description	Page
IEEE 488.2 standard commands		
*CLS	Clears the status register.	122
*ESE {*n*}	Sets the value (0–255) of the Status Enable register.	122
*ESE?	Queries the current value of the Status Enable register.	122
*ESR?	Queries the value of the Status Event Status register.	122
*IDN?	Queries the OBR for its identification string.	122
*OPC {0|1}	Sets the event bit in the Standard Event Status register, enabling (1) or disabling (0) “operation complete” event notification.	122
*OPC?	This query returns "1" if the previous operation has been completed; "0" if the previous operation is still processing.	123
*QUIT	Ends a remote session, allowing the OBR to go back to local control mode.	121
*RST	Instructs the OBR to reset all parameters to the power-on defaults.	123
*SRE {*n*}	Sets the Service Request Enable register to *n*, where *n* = 0-255.	123

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

*SRE?	Queries the current value of the Service Request Enable register.	123
*STB?	Queries the value of the Status Byte register.	123
*TST?	Performs a self-test query.	124
*WAI	Prevents the OBR from executing any further commands or queries until all pending operations have been completed.	123
Configuration commands		**Page**
CONF:COEF	Sets the temperature and strain coefficients used to generate the Temperature Change and Strain curves.	143
CONF:COEF?	Retrieves the temperature and strain coefficients used to generate the Temperature Change and Strain curves.	144
CONF:CWL {*centerWavelength*}	Sets the **Center Wavelength** (nm).	132
CONF:CWL?	Retrieves the OBR for the current **Center Wavelength** (nm).	132
CONF:DRAN	Sets the OBR distance range.	135
CONF:DRAN?	Retrieves the OBR distance range.	135
CONF:DUTL	Sets the DUT length to the value specified in meters for Extended Range mode.	136
CONF:DUTL?	Queries the current DUT length for Extended Range mode.	136
CONF:END?	Queries the OBR for the current ending wavelength (nm).	133
CONF:FWIN { 0 | 1 }	Sets the frequency domain window flag.	143
CONF:FWIN?	Retrieves whether or not a frequency domain window is applied to new measurement scans.	143
CONF:GAIN	Sets the gain vector index.	142
CONF:GAIN?	Retrieves the gain vector index.	142
CONF:GLEN {*gaugeLength*}	Sets the gauge length in cm.	138
CONF:GLEN?	Retrieves the gauge length in cm.	138

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

CONF:GRP	Sets the OBR **Group Index**.	141
CONF:GRP?	Retrieves the OBR **Group Index**.	141
CONF:INTC	Sets the OBR integration center in the units set by CONF:XUNI (page 139).	137
CONF:INTC?	Retrieves the OBR **Integration** (or **Sensing**) **Area** center in the units set by CONF:XUNI (page 139).	138
CONF:INTS	Sets the OBR **Integration** (or **Sensing**) **Area** start in the units set by CONF:XUNI (page 139).	137
CONF:INTS?	Retrieves the OBR **Integration** (or **Sensing**) **Area** start in the units set by CONF:XUNI (page 139).	137
CONF:INTW	Sets the OBR **Integration Width** (or **Sensing Range**) in the units set by CONF:XUNI (page 139).	134
CONF:INTW?	Retrieves the OBR **Integration Width** (or **Sensing Range**) in the units set by CONF:XUNI (page 139).	135
CONF:RANG {*scanRange*}	Sets the **Scan Range** in nanometers.	133
CONF:RANG?	Queries the OBR for the current **Scan Range** (nm).	134
CONF:RATE	Sets the laser sweep rate in nm/sec.	140
CONF:RATE?	Queries the laser sweep rate in nm/sec.	141
CONF:RESG?	Retrieves the **Resolution Bandwidth** in GHz.	141
CONF:RESP?	Retrieves the **Resolution Bandwidth** in picometers.	141
CONF:SFIL	Sets the **Spatial Resolution Filter**, or smoothing filter flag on (1), or off (0). Data can be filtered after a scan.	142
CONF:SFIL?	Retrieves the **Spatial Resolution Filter** flag.	142
CONF:SRAN	In optional Sensing mode (page 47), sets the OBR **Sensing Range** in the units set by CONF:XUNI (page 132).	136
CONF:SRAN?	Retrieves the OBR **Sensing Range** in the units set by CONF:XUNI (page 132).	137
CONF:SRBW	Sets the spatial **Resolution Bandwidth** (mm).	141

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

CONF:SRBW?	Retrieves the spatial **Resolution Bandwidth** in millimeters.	141
CONF:SRFW	Sets the **Spatial Resolution Filter** width (ns).	142
CONF:SRFW?	Retrieves the **Spatial Resolution Filter** width in nanoseconds.	142
CONF:SSPA	Sets the **Sensor Spacing** in cm.	138
CONF:SSPA?	Retrieves the **Sensor Spacing** in cm.	139
CONF:STAR {*startWavelength*}	Sets the *startWavelength* (nm) for the scan.	133
CONF:STAR?	Queries the OBR for the current start wavelength (nm).	133
CONF:XUNI	Sets the x-axis units being used to specify the **Integration** (or **Sensing**) **Area**. 0 : nanoseconds 1 : meters 2 : feet 3 : inches 4: millimeters	139
CONF:XUNI?	Queries the x-axis units being used to specify the **Integration** (or **Sensing**) **Area**. 0 : nanoseconds 1 : meters 2 : feet 3 : inches 4: millimeters	139
Data capture and retrieval commands		**Page**
FETC:FDET? {*trace, graphType, decimate*}	Retrieves additional detail for the frequency domain curves: integrated insertion loss (dB) for *graphType* = 0, and average delay (ns) for *graphType* = 1 or 2.	152
FETC:FREQ? {*trace*}	Queries the OBR for the starting frequency and the increment size, both in units of GHz, for the *trace* specified (A-E).	144

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

FETC:FSIZ? {*trace, domain, graphType, decimate*}	Retrieves the size of the data array for the specified variables: *Trace* can be A, B, C, D or E. *Domain* = 0 for the time domain, 1 for frequency domain. *GraphType* values for the time *domain* (0): 0 = Amplitude 1 = Linear Amplitude 2 = Polarization States 3 = Phase Derivative 4 = Amplitude (dB) 5 = Spectral Shift (only on some instruments) 6 = Temporal Shift (only on some instruments) 7 = Strain (only on some instruments) 8 = Temporal Shift (only on some instruments) *GraphType* values for the frequency *domain* (1): 0 = Return Loss 1 = Linear Amplitude 2 = Polarization States 3 = Group Delay *Decimate*: 1 = use decimation, 0 = return all points.	145
FETC:GNAM?	Retrieves the available graph names for all numeric values of *graphType* for both time and frequency domain, as listed above under FETC:FSIZ?	146

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

FETC:GSTR? {*domain, graphType, xUnits*}	Retrieves the graph title or name, the Y-axis label, and the X-axis label for the specified *domain, graphType, and xUnits. Domain* = 0 for the time domain, 1 for frequency domain. *GraphType* values for the time *domain* (0): 0 = Amplitude 1 = Linear Amplitude 2 = Polarization States 3 = Phase Derivative 4 = Amplitude (dB) 5 = Spectral Shift (only on some instruments) 6 = Temporal Shift (only on some instruments) 7 = Strain (only on some instruments) 8 = Temporal Shift (only on some instruments) *GraphType* values for the frequency *domain* (1): 0 = Return Loss 1 = Linear Amplitude 2 = Polarization States 3 = Group Delay *xUnits* values for the time *domain* (0): 0 = time (ns) 1 = length (m) 2 = length (ft) 3 = length (in) 4 = length (mm) *xUnits* for the frequency *domain* (1): 0 = wavelength (nm) 1 = frequency (GHz) 2 = frequency (THz)	146
FETC:INTL? {*trace*}	Retrieves the loss of the current **Integration** (or **Sensing**) **Area** for the specified *trace*.	153
FETC:LENE? {*trace*}	Retrieves the end length for the specified *trace*.	154
FETC:LENS? {*trace*}	Retrieves the start length for the specified *trace*.	154

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Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

FETC:MDET? {*trace*}	Queries the OBR for current measurement **Details** for the *trace* specified (A-E).	150
FETC:MEAS? {*trace, domain, graphType, decimate*}	Retrieves the Y-axis data for the specified parameters. (For variable definitions, see “FETC:FSIZ? above.)	147
FETC:RAW? {*trace*}	Retrieves the raw S and P data for the specified *trace*.	150
FETC:RSIZ? {*trace*}	Retrieves the size of the raw S and P data for the specified *trace*.	151
FETC:TIMS? {*trace*}	Retrieves the start time in nanoseconds for the specified *trace*.	153
FETC:TIME? {*trace*}	Retrieves the end time for the specified *trace*.	154
FETC:TINC? {*trace*}	Queries the OBR for the time increment of the **Time Domain** X-axis in nanoseconds (ns) for the *trace* specified.	153
FETC:WL? {*trace*}	Retrieves the starting wavelength (nm) for the specified *trace*.	152
FETC:WLC? {*trace*}	Retrieves the **Center Wavelength** (nm) for the specified *trace*.	152
FETC:WLE? {*trace*}	Retrieves the ending wavelength (nm) for the specified *trace*.	152
FETC:XAXI? {*trace, domain, units, decimate*}	Retrieves the X-axis data for the specified variables: *Trace* can be A, B, C, D or E. *Domain* = 0 for the time domain, 1 for frequency domain. *Units* for the time *domain* (0): 0 = time (ns) 1 = length (m) 2 = length (ft) 3 = length (in) 4 = length (mm) *Units* for the frequency *domain* (1): 0 = wavelength (nm) 1 = frequency (GHz) 2 = frequency (THz). *Decimate*: 1 = use decimation, 0 = return all points.	149
System level commands		**Page**

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Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

SCAN	Tells the OBR to execute an optical **Scan** based on the configured system parameters.	124
SYST:ACQ?	Queries whether data has been acquired (1) or not (0).	131
SYST:ALIG	**Aligns** the optics	126
SYST:ALIG?	Queries the OBR if the optics are aligned (1) or not (0).	127
SYST:CAL	**Calibrates** the system.	127
SYST:CAL?	Queries the system calibration status. Returns “1” if the system is calibrated successfully or “0” if it is not.	127
SYST:CALF {0, filename}	Sets the name of the calibration file. If the filename is not specified, this command sets calibration file to the default filename, obrCal_refl.	128
SYST:CALF? 0	Retrieves the name of the calibration file.	129
SYST:COPY {*source, destination*}	Copies data from the *source* trace (A-E) to the *destination* trace (A-E).	131
SYST:ERR?	Returns a numeric error code. Zero (0) indicates no error; *i.e.* the last command or query completed successfully. Any non-zero number indicates that an error has occurred. A description of the error may be retrieved with the query SYST:ERRD?	126
SYST:ERRD?	Retrieves the detailed error description for the most recent remote operation.	126
SYST:GET? {*trace*}	Queries whether data is loaded in the specified *trace* (A-E).	131
SYST:LASE {0|1}	Turns the laser on (1) or off (0).	125
SYST:LASE?	Queries if the laser is on (1) or off (0).	126
SYST:LAST?	Queries the last remote command or query processed	132
SYST:LOAD {*"filename.obr", trace*}	Loads the external file specified in quotes as a source of data reference for the measurement.	129
SYST:ON?	Queries whether the OBR is on (1) or off (0).	125
SYST:RDY?	Queries if the OBR is ready to scan (1) or not (0).	126

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

SYST:RLDC	Reloads the most recent valid calibration file into memory.	128
SYST:SAT?	Queries whether the detectors were saturated during the previous scan.	129
SYST:SAVE {*“filename.obr”, trace*}	Saves the specified *trace* (A-E) data as a binary file using the specified filename. The file name must be in quotes, and the file type ".obr" must be specified. If no *trace* is specified, the data in *Trace A* will be saved.	130
SYST:SAVT {*“filename.txt”, trace, domain, graphType, units, spatialResolution*}	Saves the current data from the *trace* specified (A-E) as text or spreadsheet data in the *path* specified in quotes, based on the following variables: *Trace* can be A, B, C, D or E. *Domain* = 0 for the time domain, 1 for frequency domain. *GraphType* can take values from 0 to 8, depending on the *domain* specified, as shown in the table on page 145. *Units* for the time *domain* (0): 0 = time (ns) 1 = length (m) 2 = length (ft) 3 = length (in) 4 = length (mm) *Units* for the frequency *domain* (1): 0 = wavelength (nm) 1 = frequency (GHz) 2 = frequency (THz). *SpatialResolution* sets the spatial **Resolution Bandwidth** (mm).	130
SYST:SPOT {*center, centerUnits*	Tells the OBR to execute an optical **Spot Scan** centered about the specified *center.* *CenterUnits*: 0 = time (ns) 1 = length (m) 2 = length (ft) 3 = length (in) 4 = length (mm)	124

Table 7-1: Alphabetical Summary of GPIB and TCP/IP Commands

SYST:SSEG {*“filename”, trace*}	Saves as a binary file the segment of the trace defined by the **Integration** (or **Sensing**) **Area**.	130
SYST:VER?	Queries the software version.	125
SYST:WARM?	Queries if the laser is at operating temperature (1) or not (0).	125
SYST:WCLF?	Queries whether the wavelength calibration failed during the previous scan.	128
SYST:WTIM?	Displays the time remaining on the system one hour warm-up timer.	125

Chapter 8

Measurement Theory

The Luna OBR utilizes swept-wavelength interferometry to interrogate the device or system under test. This technique measures the full scalar response, including both phase and amplitude information. The amplitude of the time domain data is equivalent to a traditional optical time domain reflectometry (OTDR) measurement.

Fiber Optic Interferometry

The OBR uses swept-wavelength coherent interferometry. Here this technique is presented at an introductory level. For more information see the references at the end of this section.

The two basic types of fiber interferometers are shown in Figure 8-1. A Mach-Zehnder design uses one 3 dB coupler to split the light, and another 3 dB coupler to recombine the light. In general, the two paths between the couplers are of different lengths. A detector is placed at the output of the second coupler. A Michelson interferometer uses a single 3 dB coupler to both split and recombine the light. Mirrors are placed at each of the outputs on one side of the coupler, and in general the two paths are of different lengths. On the other side of the coupler, one lead is used to inject the light, and the other is directed to a detector.

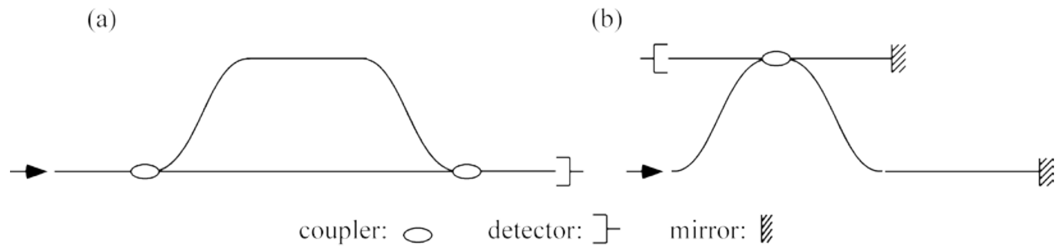

Figure 8-1. Two basic types of fiber interferometers: (a) Mach-Zehnder and (b) Michelson.

Both of these interferometer designs can be treated in a basic way using the same set of mathematics. Consider an input field of the form

$$E_{in} = E_0(t)e^{-i\omega(t)t},$$

where ω is angular optical frequency, and $\omega(t)$ describes the instantaneous frequency of the tunable laser source.

The spatial dependence of the signal may be ignored because the light is detected only at a single point. At the first coupler, the input field is split into two fields, E_1 and E_2. After propagating through different lengths of fiber, the two fields are recombined, and the resulting field at the detector is

$$E_{out} = E_0(t+\tau_1)e^{-i\omega(t+\tau_1)t} + E_0(t+\tau_2)e^{-i\omega(t+\tau_2)t},$$

where τ_1 and τ_2 are the delays through the two paths of the interferometer.

The electrical output of the detector is proportional to the optical intensity, I, which is given by the square magnitude of the electric field:

$$I(\omega) = |E_0(t)|^2 + |E_0(t-\tau)|^2 + 2E_0(t)E_0(t-\tau)\cos[\omega(t)\tau] \quad ,$$

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where the time delay difference between the interferometer paths $\tau = \tau_1 - \tau_2$.

Optical Network for OBR

A schematic of Luna’s OBR optical network is shown in Figure 8-2. The optical system is comprised of a tunable laser source (TLS), an interferometer (the DUT or device under test), and a detector.

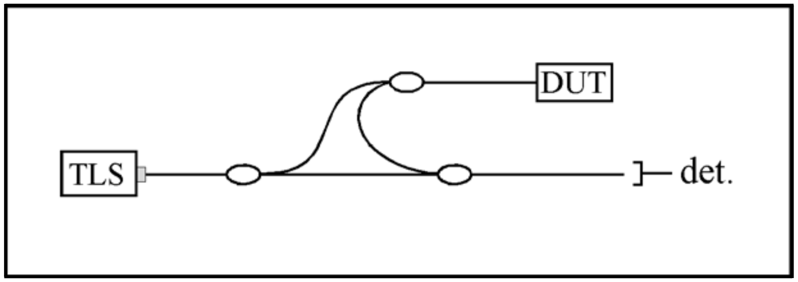

Figure 8-2. OBR optical network.

The basic idea from the previous section can be applied to device characterization by including a device under test (DUT) in one arm of a Mach-Zender interferometer, as shown in Figure 8-2. We can describe the DUT by its frequency domain linear transfer function, $H(\omega)$; the linear transfer function contains information about the amplitude, $\rho(\omega)$, and phase, $\phi(\omega)$, response of the DUT and is given by $H(\omega) = \rho(\omega)e^{i\phi(\omega)}$. Given the amplitude and phase response, the detected power is proportional to the intensity, *I*, given by

$$I = |E_0(t)|^2 + |E_0(t-\tau)|^2\rho(\omega)^2 + 2\rho(\omega)E_0(t)E_0(t-\tau)\cos[\omega(t)\tau - \phi(\omega)].$$

Next a Fourier transform is performed allowing the three terms in the above expression to be separated spectrally. Note that the first two terms will have only low frequency characteristics, and thus will appear at or near $t = 0$ in the time-domain. The device information resides in the third term of this expression, called the *interference term*. The interference term oscillates at the frequency $\omega(t)\tau$, while the other terms do not oscillate. Its location in the time-domain will be determined by the delay difference τ between the two arms of the interferometer. Provided that τ is large enough, the device response will be separable from the low frequency terms, and thus measurable. The Luna OBR is designed such that the internal delay path through the device under test is long enough such that the low frequency terms will not influence the measurement, even for very short devices. Thus the OBR operates with no dead zone.

The Fourier transform of reflected optical intensity (*I*) for a short length of single-mode fiber as the DUT is plotted in Figure 8-3 (a). Figure 8-3 (b) shows the selected segment that contains the device information. Because the initial data was acquired as a function of optical frequency, ω, the transformed data is a function of time. For this reason, the transformed data is referred to as *time domain* data.

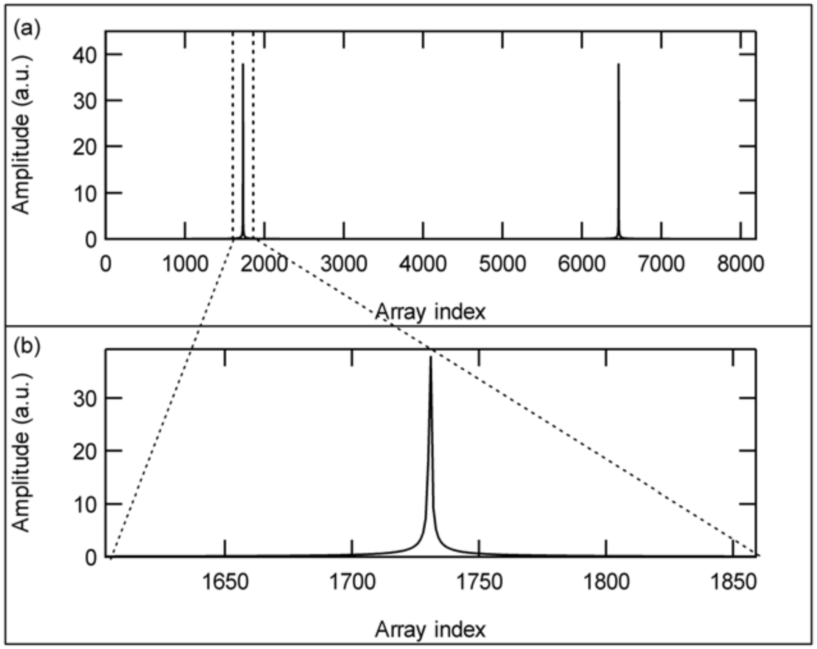

Figure 8-3. (a) The Fourier transform of interference fringes. (b) The segment of the time domain data that contains device information.

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If there are multiple reflecting interfaces within the device under test, each interface will contribute a term to the interference pattern and a peak in the time-domain located at the corresponding delay.

In order to more easily locate the source of reflections within a device, the time-domain data can be scaled in units of length, using the speed of light and the group index of the DUT.

To arrive at a measure of the frequency response of the device, an inverse Fourier transform is performed on only the section of the time-domain data that contains the device response. The OBR software allows the user to select any portion of the time-domain data so the response due to different optical paths or interfaces can be separated and measured independently.

Once the data has been transformed back into the frequency-domain, the calibrated amplitude response yields the loss of the test device. The derivative of the phase response yields the group delay.

Fiber Interferometry: References

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M.M. Ohn, S.Y. Huang, S. Sandgren, R. Measures, T. Alavie, “Measurement of fiber grating properties using an interferometric and Fourier-transform-based technique,” **WJ2**, *Optical Fiber Communication Conference*, March 1997.

M. Froggatt, J. Moore, and T. Erdogan, “Full complex transmission and reflection characterization of a Bragg grating in a single laser sweep,” **WB1**, *Optical Fiber Communication Conference*, March 2000.

M. Froggatt, E. Moore, and M. Wolfe, “Interferometric measurement of dispersion in optical components,” **WK1**, *Optical Fiber Communication Conference*, March 2002.

U. Glombitza and E. Brinkmeyer, “Coherent frequency-domain reflectometry for characterization of single-mode integrated-optical waveguides,” *J. Lightwave Tech.* **11**, 1377-1384, 1993.

Resolution Bandwidth Calculations

Because the frequency- and time-domain data are related to one another by a discrete Fourier transform, the width of the visible window in the time domain determines the resolution of the data in the frequency (wavelength) domain. If the width of the visible portion of the time domain is denoted Δt_f and given in units of nanoseconds, then the resolution bandwidth (RBW) of the frequency domain data is given by

$$RBW\,[\text{GHz}] = \frac{1}{\Delta t_f}$$

or

$$RBW\,[\text{pm}] = \frac{\lambda^2}{c\Delta t_f},$$

where λ is the center scan wavelength and c is the speed of light in a vacuum.

Spatial Resolution Calculations

The **Spatial Resolution** field in the **Data Processing** area sets the length of the box-car filter applied to the amplitude data in the time domain. This filter assigns each location in the measurement with the simple sum of all the adjacent points within the range of the filter resolution setting. Because this is not a weighted average, localized reflections—like those at the end of a fiber—will have a rectangular shape equal to the width of the control setting. If the **Spatial Resolution** is set below the minimum achievable resolution, the software will coerce it to the actual minimum value and thus the data is unfiltered.

Integration Width (or Sensing Range)

The **Integration Width** field in the **Data Processing** area controls the length of the segments centered on the vertical cursors, which are used to calculate the average loss within and between the two highlighted segments. The width of this segment determines the width of the lower graph X-axis.

Note: When **Options** > **Sensing Enabled** is on or checked (if purchased, see page 187), the fields in the **Data Processing** area change. To control the width of the highlighted area in **Sensing Mode**, change the **Sensing Range** in the **Data Processing** area.

Return Loss and Differential Loss

When the vertical cursors are on in the upper graph, the average return loss is calculated over the two **Integration Widths** (or **Sensing Ranges**, in **Sensing Mode**) and displayed in the upper right as **Ret Loss (dB)**. For example, if the entire time domain axis is given by $t \in [0, T]$ and the data is highlighted at a cursor such that $t \in [t_1, t_2]$, then the average return loss at that cursor is given by

$$RetLoss = 10\log\frac{\sum_{t_1}^{t_2}\left|\tilde{h}_j\right|}{\sum_{0}^{T}\left|\tilde{h}_j\right|},$$

where $\tilde{h}_j$ is the impulse response, further defined below under “Time Domain Amplitude and Amplitude (dB)” on page 180.

The differential loss (**Diff Loss (dB)**) displayed in the graph area is simply the difference between the return losses at each cursor, divided by two.

The differential loss is calculated by summing all of the power, *p*, within the highlighted segment around the first cursor, and dividing this sum by the sum of the power within the highlighted segment around the second cursor. The loss is calculated as five times the log of this ratio (shown below) because the loss is accumulated twice: once for the light to get to the particular segment, and once for it to return from the segment.

$$Differential\ Loss = 5\log\left|\frac{\sum_{k=C_1}^{N} p_k}{\sum_{k=C_2}^{N} p_k}\right|$$

N is the number of points specified in the **Integration Width** field (or **Sensing Range** field, in **Sensing Mode**). C_1 and C_2 are the start positions for the two segments integrated.

Standard Parameter Calculations

As mentioned above, the OBR uses coherent interferometry to measure the linear transfer function, $H(\omega) = \rho(\omega)e^{i\phi(\omega)}$, of the DUT. (See “Optical Network for OBR” on page 174.) From this the loss, dispersion and time domain parameters are extracted.

Time Domain Amplitude and Amplitude (dB)

Using the equation above for the linear transfer function, $H(\omega)$, the impulse response is given by the Fourier transform of the transfer function,

$$\tilde{h}_j = FFT\{H(\omega)\}_j \ ,$$

where $FFT\{H(\omega)\}$ denotes the Fast Fourier Transform of $H(\omega)$. The index j indicates the location in the data array, and corresponds to time.

The **Amplitude (dB)** curve is the time domain linear amplitude data plotted on a log scale, according to the following relation:

$$Amp[dB]_j = 10\log[|\tilde{h}_j|] \quad .$$

8

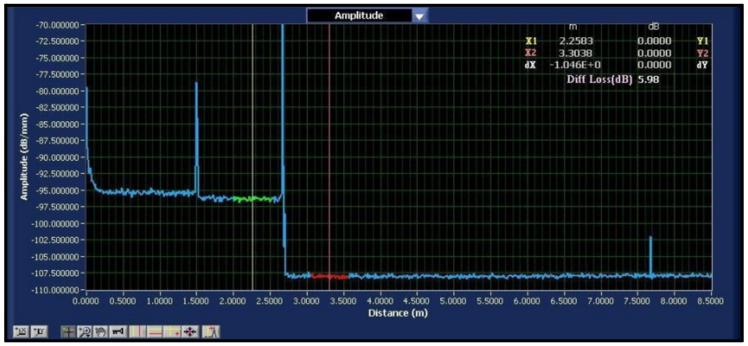

*Figure 8-4. Time domain **Amplitude** data for a switch.*

Note that **Amplitude** has units of dB/mm, as seen above, while **Amplitude (dB)** has units of dB.

The **Amplitude** curve is the time domain **Linear Amplitude** (see below), normalized by the number of data points in 1 millimeter, converted to a log scale. The number of data points in 1mm is dependent on the **Start**, **End** and **Wavelength Range** of the **Scan**. Thus, displaying the time domain **Amplitude** in these units allows for easy comparison between data sets taken using different wavelengths, since the nominal scatter level expressed in dB/mm remains constant.

Time Domain Linear Amplitude

The linear amplitude is the $|\tilde{h}_j|$ plotted on a linear scale.

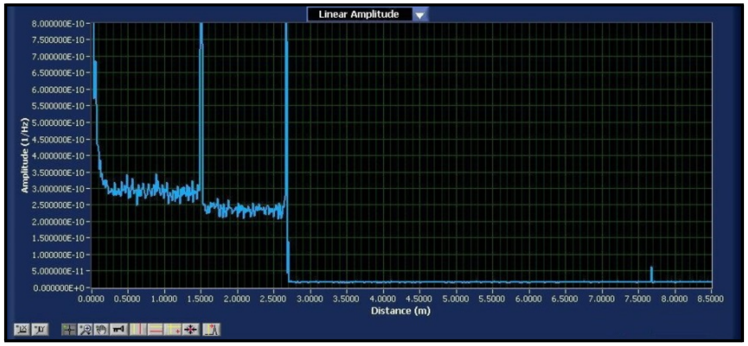

*Figure 8-5. Time domain **Linear Amplitude** data for a switch.*

Time Domain Polarization States

The OBR detects the power returned in two orthogonal polarization states. The power in these two states can be summed to form the total power returned from a particular location in the fiber. This summation is the blue curve displayed in the linear and logarithmic amplitude plots. (See Figure 8-6 below.) In some cases, particularly where birefringence is present, it is useful to look at the power returned in each of the polarization states. The polarization graph shows these two power levels in red and yellow, as well as the sum of the powers in blue.

8

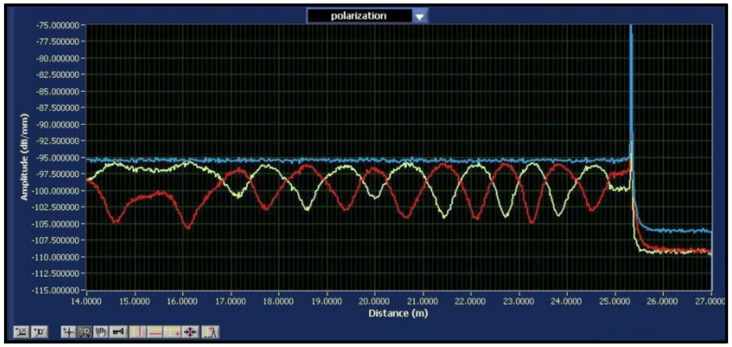

*Figure 8-6. **Polarization** data on spooled fiber.*

Time Domain Phase Derivative

The time domain phase derivative plot is the derivative of the phase of the impulse response with respect to time. Note that the time derivative of phase is the definition of optical frequency, so this derivative can be scaled as a wavelength. For a device with a distributed impulse response, the time domain phase derivative shows the wavelength distribution as a function of time for an infinitely short pulse as it is dispersed by the device. Another way to think of the time domain phase derivative is it represents the “wavelength” of the device under test. It is therefore especially meaningful for wavelength conditioning devices and filters.

In terms of the impulse response $\tilde{h}_j$ defined above, the time domain phase derivative, PD_j, is defined as

$$PD_j = \frac{2\pi c \Delta t}{\arg(\tilde{h}_{j+1}\tilde{h}_j^*)},$$

where c is the speed of light in a vacuum and Δt is the difference in time between index j and index $j+1$.

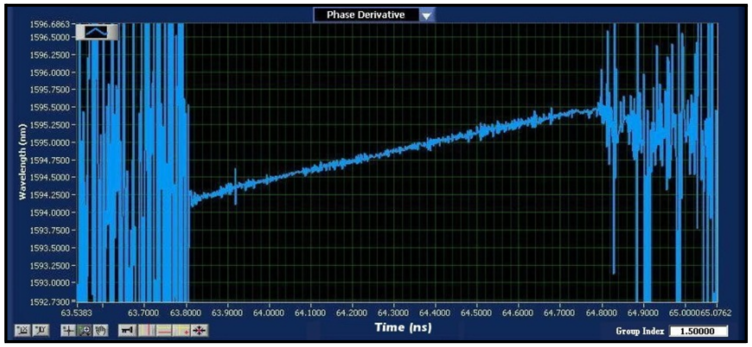

*Figure 8-7. **Phase Derivative** of the time domain response of a fiber Bragg grating.*

Time Domain Magnitude Difference

This parameter allows the user to display the difference in magnitude between **Trace A** and the **Reference Trace** in the time-domain.

Frequency Domain Return Loss

Return loss is the ratio of optical power output by the device to the optical power input to the device, and is expressed in dB. In terms of the transfer function, it is defined as

$$RL_i = 20Log(E_r / E_{in}).$$

where the subscript "i" corresponds to the "i^{th}" data point, E_r is the reflected field and E_{in} is the input field.

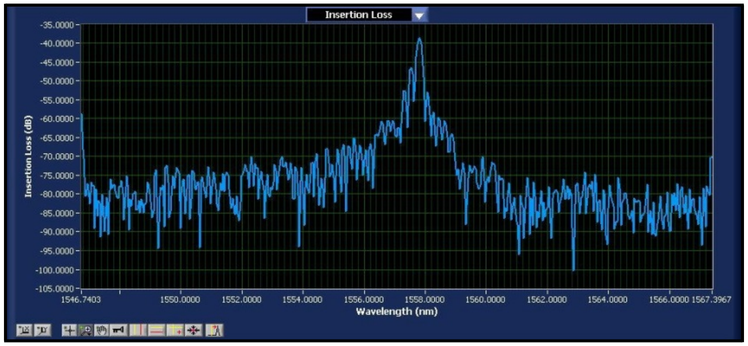

*Figure 8-8. **Return Loss** data of a fiber Bragg grating.*

Frequency Domain Group Delay

Group delay (GD) is defined to be the rate of change of phase as a function of frequency. Physically, this property corresponds to the delay experienced by the sinusoidal envelope of a modulated optical signal as it propagates through the device. In terms of the transfer function, the group delay is given by

$$GD_i = \frac{\arg(H_{i+1}H_i^*)}{\Delta\omega},$$

where $\arg(z)$ denotes the argument (phase) of the complex number z, and $\Delta\omega$ is the change in optical frequency from index i to index $i+1$.

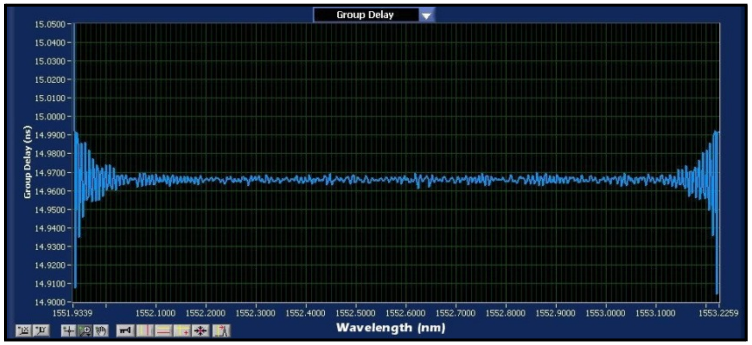

*Figure 8-9. **Group Delay** data for a patch cord.*

Frequency Domain Window

Some OBR users have noted that the reflectance peaks from strong reflection events (generally with higher than -45 dB return loss) exhibit marked broadening at the base. These side band tails can sometimes obscure the peak of a weak reflector very near a strong reflector peak. They can also overwhelm the nearby Rayleigh scatter level, making insertion loss measurements near the base of the strong reflection peak difficult. Using the **Frequency Domain Window** option significantly diminishes reflection peak side band tails.

The window is applied to all newly scanned data by selecting **Options > Display Options > Apply Frequency Domain Window**. There is no significant scan or calculation time penalty associated with selecting this option.

The effects of the Frequency Domain Window are illustrated in Figures 8-10 and 8-11. Figure 8-10 shows the reflection trace of a FC/PC connector with a clear plastic cap covering the ferrule. In the normal trace (blue), the reflections of the end cap surfaces are barely visible above the side band tail of the connector. Applying the Frequency Domain Window produces a trace (white) which suppresses the side band tails and greatly enhances the contrast of the much weaker end cap reflections just a few millimeters away from the connector.

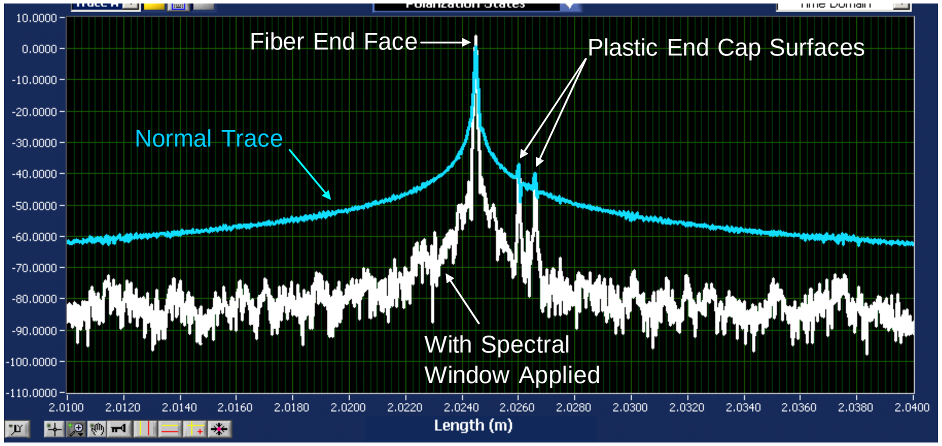

Figure 8-10. OBR traces of a FC/PC connector with a clear plastic cap over the ferrule with (white) and without (blue) a Frequency Domain Window applied. Each major x-axis division is 2 mm.

Another example which demonstrates the usefulness of the Frequency Domain Window function is illustrated in Figure 8-11. In this example, a series of short patch cables are connected to the front panel of the OBR. A pair of FC/APC connectors at the front panel at L = 0 m is followed by a pair of ST connectors at L = 0.25 m, followed by a lossy FC/APC connector pair at 0.50 m, and a final FC/APC connector pair at L = 1.0 m. In the normal trace (blue), the side band tails from the ST connector pair overwhelm the nearby fiber Rayleigh scatter, making an accurate measure of the insertion loss between nearby connections impossible. When the same set of patch cables are scanned with the Frequency Domain Window applied, a new trace is produced (white) in which the side band tails of the ST connection at 0.25 m are suppressed and a large insertion loss at the connection at 0.5 m is now obvious.

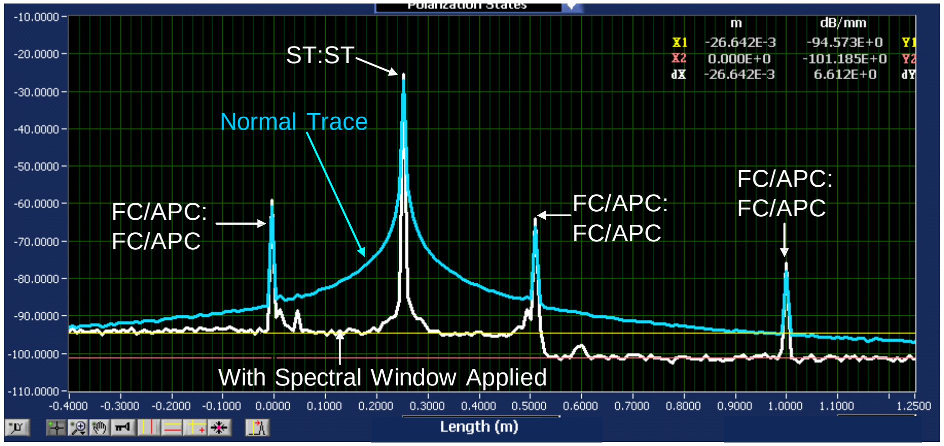

Figure 8-11. OBR traces of a series of short patch cables with (white) and without (blue) a Frequency Domain Window function applied. Each major x-axis division is 10 cm.

How Frequency Domain Window Effects Measurements

When a frequency domain measurement for a cursor-defined section of the upper graph trace is displayed in the lower graph, the effects of the Frequency Domain Window are removed by multiplying through by the inverse of the window function.

8

Return Loss

Return Loss (RL) values measured with the upper graph cursors, however, may be altered by the Frequency Domain Window if the reflection event being measured has significant RL variation in the optical frequency domain. Connectors and splices tend to have spectrally flat RL, but fiber Bragg gratings and thin film filters do not. For this reason, the Frequency Domain Window should be left off when measuring the RL of gratings and filters. If you are not sure if the RL spectrum of your device under test is flat, you can simply check by highlighting the device in the upper graph with a vertical cursor and selecting the frequency domain setting near the upper right corner of the lower graph.

Insertion Loss

Insertion Loss (IL) measurements are made by integrating over the Rayleigh scatter in separate parts of the network under test. Since fiber Rayleigh scatter is spectrally uniform, the frequency window function will not significantly alter the measured Rayleigh scatter amplitude.

Distributed Sensing

Distributed strain and temperature measurements are made by sensing the spectral shift in the fiber Rayleigh scatter. Since the higher and lower parts of the scanned spectrum are attenuated by the frequency domain filter, the effective measurable temperature and strain range is cut roughly in half. For this reason it is advisable but not necessary to leave the Frequency Domain Window off when making distributed strain or temperature measurements. It is possible but not advisable to use a reference with the window applied and obtain subsequent data with the window off, or vice-versa.

Optional Distributed Sensing Parameters

Five distributed sensing parameters can also be measured by the OBR, with a purchased software option. The OBR uses swept-wavelength interferometry (SWI) to measure the Rayleigh backscatter as a function of length in optical fiber with high spatial resolution. Rayleigh backscatter in optical fiber is caused by random fluctuations in the index profile along the fiber length. Scatter amplitude is a random but static property of a given fiber and can be modelled as a continuous weak fiber Bragg grating (FBG) with a random period.

The physical length and index of refraction of the fiber are intrinsically sensitive to environmental parameters: temperature and strain, and to a lesser extent, pressure, humidity (if the fiber coating is hydroscopic), electromagnetic fields, etc. In most practical cases the effects of temperature and strain will dominate the spectral response of the Rayleigh backscatter, so we concentrate our examination on these parameters.

Changes in the local period of the Rayleigh scatter cause temporal and spectral shifts in the locally-reflected spectrum. These shifts can then be scaled to form a distributed sensor. This SWI-based technique enables robust and practical, distributed temperature and strain measurements, with millimeter-range spatial resolution over tens to hundreds of meters of standard fiber, with strain and temperature resolution as fine as 1 $\mu\varepsilon$ and 0.1 °C.

Measurement Technique

A strain or temperature sensor is formed by first measuring and storing the Rayleigh scatter signature of the fiber under test (FUT) at an ambient state; this data is stored as the **Shift Reference**. Then the scatter profile is measured at a later time with strain or heat applied at some point along the length of the fiber. (For more details, see “Measurement Technique” on page 61.) The scatter profiles from the two data sets are then cross correlated along the segment highlighted by a vertical cursor, in increments of Δz, which represents an individual sensing element.

It is important to note that the **Gauge Length**, Δz, affects the spectral resolution and the signal-to-noise ratio of the measurement. (The **Gauge Length** is set by the user in the **Data Processing** area of the main screen.) There is, therefore, a relationship between the spatial resolution of the measurement and its accuracy in measuring the change in strain or temperature. The longer the segment used, the better the temperature accuracy. However, if the strain or temperature varies rapidly with position, a smaller segment size is often necessary to prevent the distortion in the position scale from blurring the cross correlation spectra.

When the user highlights a portion of temporal domain data in the upper graph using the vertical cursors, they can view the spectral data for the highlighted portion in the lower graph. (For more information, see “Distributed Sensing Measurements” on page 59.) A shift in the spectrum of this data in response to strain ε or temperature T is analogous to a shift in the resonance wavelength $\Delta\lambda$ or the spectral shift $\Delta\nu$ of a Bragg grating:

8

$$\frac{\Delta\lambda}{\lambda} = -\frac{\Delta\nu}{\nu} = K_T \Delta T + K_\varepsilon \varepsilon \ ,$$

where λ and ν are the mean optical wavelength and frequency, and K_T and K_ε are the temperature and strain calibration constants, respectively. The default values for these constants are set at values common for most germanosilicate core fibers: K_T = 6.45 x 10^{-6} °C^{-1} and K_ε = 0.780. The OBR software allows the user to set their own values for these constants, according to their specific application. (See “Temperature Change and Strain Coefficients” on page 60.)

The values for K_T and K_ε are somewhat dependent on the dopant species and concentration in the core of the fiber, but also to a lesser extent on the composition of the cladding and coating. Variations of 10% in K_T and K_ε between standard telecom fibers are common; larger variations may be observed in specialty fiber, such as polarization maintaining (PM) fiber or Erbium-doped fiber.

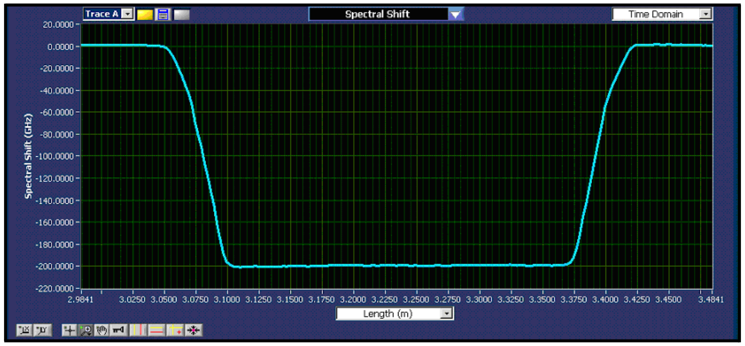

Figure 8-12. ***Spectral Shift*** *result for a constant strain applied to a 320 mm length of fiber.*

Temperature Change and Strain

Currently the OBR is not configured to simultaneously measure temperature and strain shifts. In the absence of strain, however, the temperature change be written as:

$$\text{Temperature Change} = \Delta T = -\frac{\bar{\lambda}}{cK_T}\Delta\nu\,,$$

where $\bar{\lambda}$ is the center wavelength of the scan and c is the speed of light. Similarly, in the absence of a temperature change, the strain can be written as:

$$\text{Strain} = \varepsilon = -\frac{\bar{\lambda}}{cK_\varepsilon}\Delta\nu\ .$$

Assuming a scan center wavelength of 1550 nm, we can substitute in the constants K_T and K_ε to yield the following conversion factors: ε = (-6.67 $\mu\varepsilon$/GHz)$\Delta\nu$, and ΔT = (-0.801 ºC /GHz)$\Delta\nu$.

Thus the distributed temperature and strain curves are merely rescaled copies of the spectral shift distribution.

Temperature Change and Strain Coefficients

The temperature change and strain curves are generated by converting the spectral shift curve from values in GHz to degrees C or microstrain. This conversion is done using a 4th order polynomial fit. The default coefficients for this fit have been set for standard SMF 28 fiber. The user can customize these coefficients for other fiber by recording the **Frequency Shift** of that fiber, while measuring temperature or strain on that fiber externally. (See “Temperature Change and Strain Coefficients” on page 60.)

Spectral Shift

In SWI the backscatter optical power $U(\nu)$ is collected in the spectral frequency domain: detectors collect light backscattered from the FUT (fiber under test) as the laser spectral frequency is tuned. The data is processed with a Fourier Transform to generate the backscatter optical power $U'(\tau)$ as a function of time delay τ, which can be scaled to show the return loss as a function of FUT length.

The spectral shift option for the lower graph divides the time domain data highlighted in the upper graph into segments and computes the backscatter spectrum for each segment. Although the backscatter spectrum appears random for a segment of fiber, it is actually determined by random fluctuations in the core index of refraction and is stable and repeatable. For a specific fiber segment *j*, the reflection spectrum is denoted as $U_j(\nu)$. If the fiber is exposed to a change in strain or temperature, the reflection spectrum will experience a shift in optical frequency $\Delta\nu_j$ and can be denoted $U_j(\nu - \Delta\nu_j)$. The shift in the reflection spectrum $\Delta\nu_j$ is computed by performing a cross correlation operation $U_j(\nu)$ on and $U_j(\nu - \Delta\nu_j)$. As shown in the equation on page 188, this spectral shift can than be related to a temperature or strain change.

8

Spectral Shift Quality

The Spectral Shift Quality is a measure of the strength of the correlation between the measurement and reference reflected spectra. This value is calculated as:

$$\text{Spectral Shift Quality} = \frac{MAXIMUM(U_j(v) \star U_j(v - \Delta v_j))}{\sum U_j(v)^2} ,$$

where U_j is the reference spectrum for a given segment of data, $U_j(\nu - \Delta\nu_j)$ is the measurement spectrum under a strain or temperature change, and the symbol ★ is used to denote the cross-correlation operator. In other words, the **Spectral Shift Quality** is the maximum value of the cross correlation of the **Reference** and measurement spectra normalized by the maximum expected value, i.e. the maximum of the reference spectra autocorrelation.

In practical use, the **Spectral Shift Quality** will be a value between 0 and 1, where 1 is a perfect correlation, and zero is uncorrelated. In general, the data sets should be considered well correlated if the **Spectral Shift Quality** is above about 0.15. Note that as **Strain** or **Temperature Change** increases, **Spectral Shift Quality** will decrease. This is expected since exposing a fiber to a change in strain or temperature induces a temporal shift as well as a temporal stretch or compression.

Temporal Shift

The temporal shift Δt results from the integrated effect of local time shifts along the FUT between the origin at the front panel of the OBR and the delay time at which the shift is being evaluated. This temporal shift is calculated from the spectral shift using the following relationship:

$$\Delta\tau(\tau)_j \approx -a_0\left(\frac{\lambda_1\lambda_2}{c\lambda_c}\right)\left(\frac{SensorSpacing}{GaugeLength}\right)\sum_{i=0}^{j}\Delta\nu_i ,$$

where the summation is over the **Gauge Length** (as set by the user in the **Data Processing** area); a_0 denotes a scaling constant; λ_1, λ_2 and λ_c are the **Start**, **End** and **Center Wavelengths** of the scan, respectively; and c is the speed of light. It is assumed that the **Temporal Shift** value is equally distributed over the **Gauge Length**. When this is not a valid assumption, the **Temporal Shift** data will become noisy; a smaller **Gauge Length** is required for the calculations to succeed. Note that when the **Sensor Spacing** is equal to the **Gauge Length**, this expression is exact.

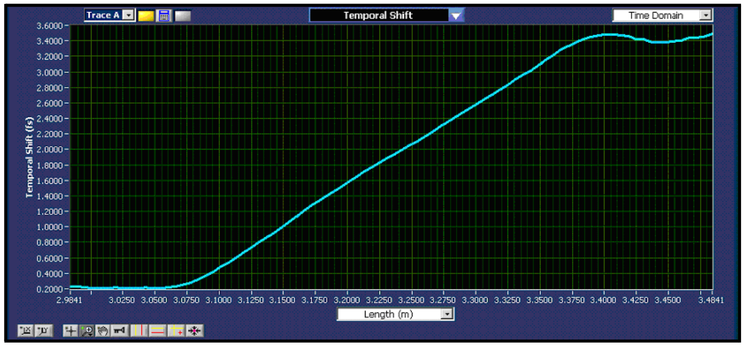

*Figure 8-13. **Temporal Shift** results for the same source data and same length range as in Figure 8-12.*

Number of Points and Resolution

The spatial resolution of the **Spectral Shift**, **Spectral Shift Quality**, **Temperature Change**, **Strain** and **Temporal Shift** measurements is determined by the **Sensor Spacing** and **Gauge Length** settings in the **Data Processing** area of the main software window. When these two settings are the same, they are equivalent to the two-point spatial resolution. The **Gauge Length** determines the segment size of the Rayleigh scatter that is used to determine the **Spectral Shift**, from which the other sensing parameters are calculated. The **Sensing Range** divided by the **Sensor Spacing** determines the number of points displayed to the user.

Distributed Sensing References

D. Gifford, B. Soller, M. Wolfe, and M. Froggatt, “Distributed Fiber-Optic Sensing using Rayleigh Backscatter,” **WB 4**, p. 5, *European Conference on Optical Communications (ECOC) Technical Digest*, Glasgow, Scotland, 2005.

M. Froggatt, B. Soller, D. Gifford, and M. Wolfe, “Correlation and keying of Rayleigh scatter for loss and temperature sensing in parallel optical networks,” *OFC Technical Digest*, paper PDP 17, Los Angeles, March, 2004.

B. J. Soller, D. Gifford, M. Wolfe, and M. Froggatt, “High resolution optical frequency domain reflectometry for characterization of components and assemblies,” *Opt. Express*, **13**, pp.666-674, 2005.

B. J. Soller, M. Wolfe, M. E. Froggatt, “Polarization resolved measurement of Rayleigh backscatter in fiber-optic components,” paper NWD3, *OFC Technical Digest*, Los Angeles, March, 2005.

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A. Kersey, M. Davis, H. Patrick, M. LeBlanc, and K. Koo, “Fiber grating sensors,” *Journal of Lightwave Technology*, **15**(8), pp. 1442-1462, 1997.

A. Othonos, “Fiber Bragg gratings,” *Rev. Sci. Instrum.*, **68**(12), pp. 4309-4340, 1997.

Y. Roa, “In-fibre Bragg grating sensors,” *Meas. Sci. Technol.*, **8**, pp. 355-375, 1997.

8

Chapter 9

Maintenance

Cleaning Connectors

It is extremely important to clean connectors before attaching optical fibers to the OBR for testing. Failure to do so may result in erroneous or noisy data.

Optical fiber connectors on devices should be cleaned before every connection to the OBR. The bulkhead connectors on the front panel of the OBR should be cleaned frequently, roughly once every 25 connections.

The optical fiber connector cleaner is used for cleaning connectors:

Mini foam swabs are used for cleaning the OBR bulkhead connectors:

The cleaning supplies used with the OBR are:

- CLETOP connector cleaner - P/N F1-6270
- CLETOP connector cleaner replacement reel - P/N F1-6271
- Mini foam swabs (50/package) - P/N F1-0005

These supplies can be ordered from:

FIS Incorporated
161 Clear Road
Oriskany, NY 13424
Web: www.fiberinstrumentsales.com
E-mail: info@fiberinstrumentsales.com.

Important

Use only cleaners approved for use with fiber optic bulkheads and fiber connectors. Do not use any type of cleaning fluid, cotton swabs, or cloths.

Using unapproved cleaning tools or fluids may result in erroneous or noisy data, or may damage the fibers and OBR components.

Cleaning Optical Fiber Connectors

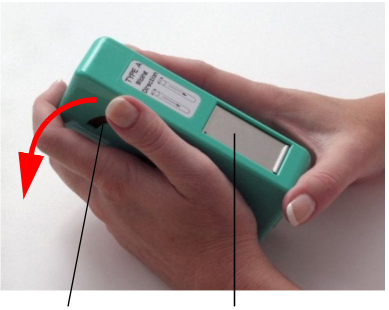
Important

Optical fiber connectors on devices should be cleaned before every connection to the OBR.

1 Expose the cleaning tape by pushing down the cover release lever.

9

Cleaning tape cover closed

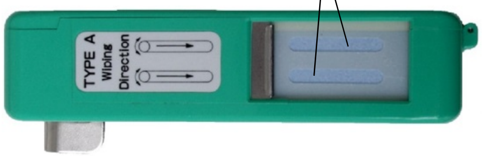


cover release lever   tape cover

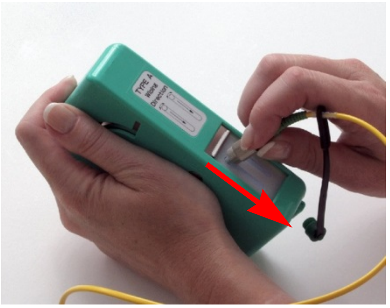
Cleaning tape cover open

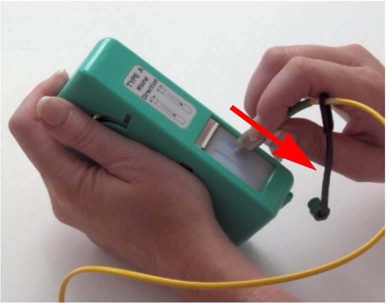
cleaning tape

The cleaner tape has two cleaning strips:



2 Holding the fiber connector perpendicular to the cleaner tape surface, swipe the tip of the connector down the first cleaning strip, then swipe on the second strip.





3 Close the cleaning tape cover before swiping another connector. This advances the cleaning tape.

Cleaning Bulkhead Connectors

Important

The bulkhead connector should be cleaned about once every 25 connections.

1 Either turn off the OBR, or turn off the laser by selecting **Tools** > **Turn Laser OFF**.

2 Make sure that no devices are connected to the OBR.

3 Turn the protective cap counterclockwise to remove it. Gently insert one of the supplied mini swabs, as shown below. Twist the swab in one direction, and then remove. *Discard miniswabs after single use.*

Figure 9-1. Remove the protective cap. Gently insert supplied mini swab, rotate in one direction, then remove.

4 Replace the protective cap to protect the connector.

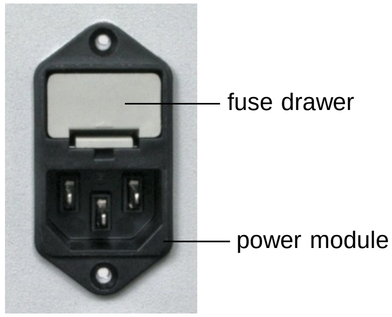
Cleaning the Case

Clean the case by wiping it with a soft cloth dampened with water or a mild, non-abrasive cleaning fluid such as window cleaner.

Caution ⚠ Do not spray any fluid directly on case surfaces. It may seep into the interior of the case and damage components.

Replacing Fuses

The fuse drawer is located on the power module on the instrument case back panel:

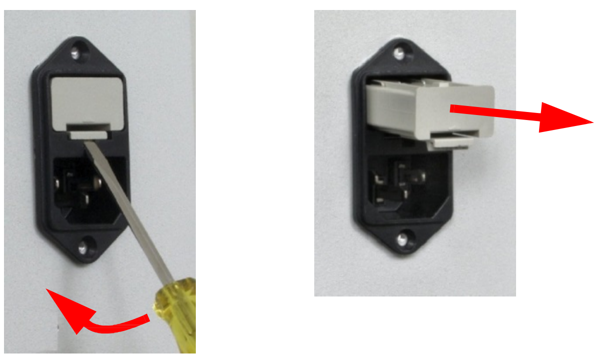


Warning

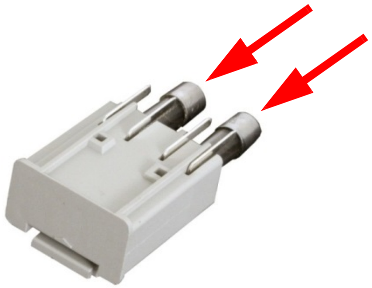
To avoid the risk of serious injury or death, ensure that the power cord is disconnected from the instrument when checking or replacing fuses.

To replace fuses

1. Disconnect the instrument power cord.
2. Place the blade of a screwdriver or similar tool in the slot at the bottom of the fuse drawer, then gently pry the drawer out of the power module.



3. Replace fuses with Bussmann AGC-2 type 2A @ 250VAC 1 ¼” x ¼” fast acting (FA) fuses, rated FS01008.



4 Push the drawer back into the power module until it snaps into place.

5 Reconnect the power cord.

Packing and Shipping the OBR

The OBR should only be packed and shipped in its original packing materials. If these have been discarded, contact Luna Technologies for packing material. To minimize physical shock during shipping, the OBR system should always be shipped via air instead of ground, by a reputable shipping service provider.

Required Packing Materials

- OBR Shipping Box (#1)
- Desktop or Laptop PC Box (#2)
- PC Monitor Box (if do not have laptop)(#3)
- OBR Shipping Foam
- PC Monitor Shipping Foam
- PC Shipping Foam
- OBR Accessory Box
- PC Accessory Box
- Sturdy packaging tape to seal the boxes

Packing Procedure

1. Check that all materials to be shipped are ready to be packed using the “Components List” on page 7.
2. Place the supplied protective cap over the detector port and turn it clockwise until tightened.
3. Obtain an OBR Shipping Box (#1).
4. Seal the bottom center and edges of the box.
5. Pack the OBR in the OBR Shipping Box using the original styrofoam insert on each side of the OBR.
6. Pack the user software, the *User Guide*, the OBR Accessory Pack, and OBR cables in the OBR Accessory Box.
7. Place the OBR Accessory Box on top of the OBR.
8. Seal the top of the box, taping the center and open edges.
9. Obtain a Luna Desktop or Laptop PC Shipping Box (#2), as applicable.
10. Seal the bottom center and edges of the box.
11. Pack the PC in the PC Shipping Box using the original styrofoam inserts on each side of the PC.
12. Pack the PC software and manuals, as well as the mouse, keyboard, and PC Power Cord in the PC Accessory Box.
13. Place the PC Accessory Box on top of the re-packaged PC.
14. Seal the top of the box, taping the center and open edges.
15. Obtain a Luna Technologies Monitor Shipping Box (#3), if applicable. Otherwise disregard the remaining steps.
16. Seal the bottom center and edges of the box.
17. Pack the monitor in the Luna Technologies Monitor Box using the original styrofoam inserts on each side of the monitor. The Monitor Box should contain the monitor, the monitor software and manuals, the power supply and the power cord.
18. Seal the top of the box, taping the center and open edges.

9

Chapter 10

Troubleshooting

This chapter describes how to troubleshoot OBR hardware and software errors. The first section describes what to do when the various **Status Bar Messages** appear. **General Troubleshooting** contains procedures for problems that occur without accompanying error messages. **Error Message Troubleshooting** explains error messages which appear in dialog boxes. The next two sections are organized roughly in the order in which a user would operate the equipment and software.

If you have problems or error messages not listed here, or if the solutions provided here do not resolve a problem, please contact Luna Technologies toll free at 1-866-LUNAOVA (1-866-586-2682) or by e-mail at support@lunatechnologies.com.

System Status Bar Messages

Please note that status bar messages are not "fatal" error messages. Rather they advise the user of the status of the instrument.

Error Message	Solution(s)
Laser Not Ready	This indicator will be displayed if the laser is not ready to perform a measurement. If this indicator does not go off within several minutes of turning on the instrument, please see "Instrument drifts out of calibration" on page 208.
Out of Alignment	Realign, then recalibrate. For instructions, see "Aligning the OBR Optics" on page 32, and "Calibrating the System" on page 33. Measurements may still be performed if this indicator is displayed on the screen, but the data may not meet the documented specifications.
Out of Calibration	Recalibrate. For instructions, see "Calibrating the System" on page 33.

Error Message	Solution(s)
Wavelength Cal Failed	This message is displayed if a measurement cannot be calibrated to the wavelength. This simply means that the data acquired is accurate in terms of the parameter displayed on the screen, but the data is shifted in either direction in terms of wavelength. This problem may occur once in a while, but the occurrences should be fairly sparse. First try to scan again or try scanning over a different wavelength range to see if the warning indicator is displayed again. If the error light persists, it generally means that the laser (not just the instrument) needs to be recalibrated. First, run the Self-Diagnostic software and send the resulting text file to Luna (as described beginning on page 211). Then you may contact Luna Technologies toll free at 866-LUNAOVA (866-586-2682) or by e-mail at support@lunatechnologies.com.
Detectors saturated, reduce gain	The detector has been saturated by a strong reflection, causing “ghost peaks.” To correct this problem, reduce the **Gain** setting in the **System Control** area by one level and retry the scan.

General Troubleshooting

The OBR or PC will not power on

Cause(s)	Solution(s)
The OBR and/or the PC is not plugged in or turned on (and the laptop battery is dead, if applicable).	The OBR and the PC require separate power cords. Plug in the OBR and/or the PC, or replace dead batteries with charged ones if using a laptop PC. Instructions for the PC battery are located in the provided PC manual. Make sure to turn on the OBR power switch on the front of the instrument, and the PC according to its instructions.
Blown fuse.	Replace the fuse. For instructions, see “Replacing Fuses” on page 198.

Laser Ready light does not come on within several minutes

Cause(s)	Solution(s)
The OBR has not stabilized to room temperature.	Allow time for the entire system to stabilize at room temperature before trying to operate.
Laser overheated because air flow to the OBR is restricted.	Move the OBR away from objects or surfaces that restrict air flow through the fan duct on the back of the OBR.
Laser overheated because of excessively high ambient temperature.	Move the OBR to a cooler environment or decrease the ambient temperature to within the OBR operating range of 10–35ºC. If all of the above conditions are met and the Laser Ready light still does not come on, run the Self-Diagnostic software and send the resulting text file to Luna (as described beginning on page 211). Then you may contact Luna Technologies toll free at 866-LUNAOVA (866-586-2682) or by e-mail at support@lunatechnologies.com.

Control software will not load

Cause(s)	Solution(s)
Generally this occurs when other software is installed on the PC.	Remove any software not originally installed on the OBR PC, then restart. If the problem persists, reinstall the OBR control software from the OBR software CD.

All software controls are disabled or unavailable

Cause(s)	Solution(s)
The instrument is not properly connected to the PC.	Ensure that the cable connecting the instrument to the PC is securely attached.

The instrument could not be configured properly due to a communication error.	Reboot the PC. Turn the instrument off and then back on again. Restart the OBR control software. If the problem persists, reinstall the OBR control software from the OBR software CD.

Control software seems to lock up

Cause(s)	Solution(s)
The hardware may have stopped responding to the software.	Exit the software, using the Windows® Task Manger if necessary. [Click Ctrl + Alt + Del, then click the Task Manger button, then select the OBR software, and click End Task.] Turn the instrument off and then back on again. Restart the OBR control software.
Multiple Luna Technologies software applications may be running at the same time.	Ensure that you are only running one control software program at a time. Software applications cannot share the OBR instrument, so running more than one at a time will produce undesirable results.
The PC has entered an unusable state.	Reboot the PC. Turn the instrument off and then back on again. Restart the OBR control software. If the problem persists, reinstall the OBR control software from the OBR software CD.

Cannot align the OBR

Cause(s)	Solution(s)
Laser not on.	Turn the laser on. Then realign after the Laser Ready light comes on. For instructions on aligning the optics, see “Aligning the OBR Optics” on page 34.

Alignment unsuccessful

Cause(s)	Solution(s)
Normal alignment procedure occasionally fails.	Retry. See “Aligning the OBR Optics” on page 34.

OBR will not scan

Cause(s)	Solution(s)
Laser not on or ready.	If the laser is not on, turn it on. Then re-scan after the Laser Ready light comes on. If the laser is on but the ready light is not lit, the laser is still warming up. Wait until the Laser Ready light comes on, then scan. If the Laser Ready indicator does not light within several minutes of turning on the instrument, see “Laser Ready light does not come on within several minutes” on page 205.
The instrument is not calibrated. (The “Out of Calibration” indicator should be lit in this case.)	Recalibrate. For instructions, see “Calibrating the System” on page 35
Optics not aligned. (The “Out of Alignment” indicator should be lit in this case.)	Realign, then recalibrate. See “Aligning the OBR Optics” on page 34, and “Calibrating the System” on page 35.
The instrument is not properly connected to the PC.	Ensure that the cable connecting the instrument to the PC is securely attached.

Excessive noise in data

Cause(s)	Solution(s)
Mechanical vibration.	Move, remove, or shut down any sources of vibration such as fans or other motor-driven equipment. Isolate the OBR from those sources.
Loose DUT connection.	Tighten the DUT (device under test) connections.
Dirty DUT or bulkhead connections.	Clean all connections. For instructions, see “Cleaning Connectors” on page 195.
OBR not aligned.	Realign, then recalibrate. For instructions, see “Aligning the OBR Optics” on page 34, and “Calibrating the System” on page 35.

OBR not calibrated.	Recalibrate. For instructions, see “Calibrating the System” on page 35.
Wrong fiber connector type.	Ensure that the fiber connectors interfacing with the front panel of the OBR are FC/APC connectors.
Incorrect or out-of-date calibration file loaded on startup.	Recalibrate. For instructions, see “Calibrating the System” on page 35.
DUT too long.	Shorten the leads or replace the DUT to comply with the length limit of the OBR. See “Specifications” on page 213 for the length limits.
Cracks in bulkhead connector alignment sleeve.	Contact Luna Technologies at 1-866-LUNAOVA or support@lunatechnologies.com for service.

No data after scan

Cause(s)	Solution(s)
Incorrect graph range settings.	Rescale the plot axes. For detailed information, see “Scaling Plot Axes” on page 69.

Unexpected or abnormal data

See “Excessive noise in data” on page 207.

Instrument drifts out of calibration

Cause(s)	Solution(s)
Temperature changes will cause the instrument to drift.	Recalibrate. For instructions, see “Calibrating the System” on page 35.

Error Message Troubleshooting

Errors can occur while operating the OBR software. These errors will be described on the screen in a standard Microsoft® Windows® dialog box, showing the numerical error code as well.

Errors on Software Startup

Instrument not referenced

Cause(s)	Solution(s)
On startup, the software attempts to load calibration data from a file. If this message is displayed, the file was not found or was found to be corrupted.	Calibrate the instrument. Once the instrument is calibrated successfully, the user will never see this message again (unless the calibration data files are deleted manually).

Configuration information could not be loaded from the instrument; the software goes into “Desktop Analysis” mode

Cause(s)	Solution(s)
The USB cable connections could be loose.	Check the connections to ensure that the cable is connected properly to both the instrument and the PC.
The instrument is not turned on.	Ensure that the instrument is plugged into the proper type of outlet and turn on the power switch.
The software is in an unknown state.	Exit and restart the software.
The hardware is in an unusable state and is not responding to the software.	Exit the software. Turn the instrument off and then back on again. Restart the PC and the control software.
The USB cable is faulty.	If the above solutions do not work, run the Self-Diagnostic software and send the resulting text file to Luna (as described beginning on page 211). Then you may contact Luna Technologies toll free at 866-LUNAOVA (866-586-2682) or by e-mail at support@lunatechnologies.com.

Errors During Calibration

Wavelength calibration failed while acquiring data

Cause(s)	Solution(s)
None of the requested scans that were acquired were properly adjusted to wavelength. Although this is not a major error when performing a measurement, it is a problem when calibrating the instrument.	Attempt the operation again. If the problem persists, re-calibrate the laser as described under “Calibrating the System” on page 35.

The optics were detected to not be aligned properly

Cause(s)	Solution(s)
This is just a warning letting the user know that the optics are not aligned properly.	The user will have the option of continuing with the calibration even without the optics aligned. It is preferable to realign, then recalibrate. For instructions, see “Aligning the OBR Optics” on page 34, and “Calibrating the System” on page 35.

Calibration data contains invalid values

Cause(s)	Solution(s)
The calibration was unsuccessful due to some problem in the hardware or software.	Attempt the calibration again. If the problem persists, run the Self-Diagnostic software and send the resulting text file to Luna (as described beginning on page 211). Then you may contact Luna Technologies toll free at 866-LUNAOVA (866-586-2682) or by e-mail at support@lunatechnologies.com.

Errors During Scanning or Referencing

Any number of errors can be displayed during a scan. However, many of the errors are not major problems and most will be isolated incidents. In those cases, the error message will be displayed during one scan and the subsequent scans will be performed without any error. If any error occurs consistently, please contact Luna Technologies toll free at 866-LUNAOVA (866-586-2682) or by e-mail at support@lunatechnologies.com

The specified timeout occurred before all of the requested data could be acquired

Cause(s)	Solution(s)
There may be a problem with the hardware.	If this problem occurs more than once at any time, exit the software. Turn the instrument off and then back on again. Restart the PC and the control software. If none of these actions fix the problem, run the Self-Diagnostic software and send the resulting text file to Luna (as described beginning on below). Then you may contact Luna Technologies toll free at 866-LUNAOVA (866-586-2682) or by e-mail at support@lunatechnologies.com.

Self-Diagnostic Software

Each Luna Technologies PC is loaded with both operating and Self-Diagnostic software. If the above-described error messages and solutions do not solve issues, please run the Self-Diagnostic software before contacting Luna. The Self-Diagnostic software outputs a text file (c:\selfdiag:txt) which will help Luna's support staff correct errors.

Running the Self-Diagnostic Software

1. Exit the OBR software (by selecting **File** > **Exit**) and any other software.
2. Go to the Windows® Start menu and select **Programs** > **Luna Technologies** > **Self-Diagnostic**.

The following window box appears:

3 Click the blue **Start** button.

4 Follow instructions as they appear.

5 When the diagnosis is finished, the window will change appearance, as shown below:

6 You may view the results and then click the red **Exit** button.

7 As instructed in the above window, send the resulting text file (c:\selfdiag:txt) as an attachment to support@lunatechnologies.com. Luna's support staff will examine the file and contact you.

Appendix A

Specifications

Parameter	Specification	Units
Electrical		
Input Voltage Range	100-250	VAC
Input Frequency Range	50-60	Hz
Operating Power	100	VA
Optical Output		
Maximum Rated Output Power	2.4	mW
Internal Laser Module Maximum Rated Output Power	10.0	mW
Emitted Wavelengths	1260-1340 or 1520-1630	nm
PC I/O		
Input/Output Devices	• CD drive • USB ports • RS-232 port • Printer port • Ethernet port • IEEE-488/GPIB (optional) • Keyboard/Mouse • Display	
Environmental		
Operating Temperature Range[1]	10-35	ºC
Storage Temperature Range	0-40	ºC
Relative Humidity (non-condensing)	< 80	%
Dimensions and Weight (Including Toughbook® PC)		

Parameter	Specification	Units
Weight (PC not included)	11.4 25	kg lbs
Case Size	366 X 345 X 165 14.42 X 13.6 X 6.5	mm in

[1]Performance criteria can only be met if the unit is operated within the proper temperature range indicated. Maintenance of an acceptable internal operating temperature depends upon proper equipment ventilation. To ensure proper ventilation, never obstruct enclosure airflow openings.

For current performance specifications, check our website at www.lunatechnologies.com

Minimum PC Requirements

Pentium 4 or Core 2 Processor

2 GB RAM

USB 2.0 port

Windows 2000/XP or Windows 7 (Vista not supported)

Screen Resolution: 1280 x 1024

(Laptop resolution setting must be > 1280 x 1024)

Class 1 Laser Product

The Luna Technologies OBR 4600 is a **Class 1 Laser Product**, which meets the requirements of Class 1 in standards **IEC 60825-1: 2001** and **2007**, and complies with **21CFR1040.10**.

Maximum rated output power: 2.4 mW

Internal laser module maximum rated output power: 10.0 mW

Emitted wavelengths: 1260 to 1340 nm or 1520 to 1630 nm

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