User Guide

FTB-5600

Distributed PMD Analyzer for FTB-500

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Telecom Test and Measurement

EXFO
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Units of Measurement

Units of measurement in this publication conform to SI standards and practices.

Version number 2.0.0

Contents

Certification Information

F.C.C. Information

Electronic test equipment is exempt from Part 15 compliance (FCC) in the United States. However, compliance verification tests are systematically performed on most EXFO equipment.

CE Information

Electronic test equipment is subject to the EMC Directive in the European Union. The EN61326 standard prescribes both emission and immunity requirements for laboratory, measurement, and control equipment. This unit has undergone extensive testing according to the European Union Directive and Standards.

EXFO CE DECLARATION OF CONFORMITY

Application of Council Directive(s):	2006/95/EC - The Low Voltage Directive 2004/108/EC - The EMC Directive And their amendments
Manufacturer's Name:	EXFO Electro-Optical Engineering Inc.
Manufacturer's Address:	400 Godin Avenue Quebec, Quebec Canada, G1M 2K2 (418) 683-0211
Equipment Type/Environment:	Test & Measurement / Industrial
Trade Name/Model No.:	FTB-5600 Distributed PMD Analyzer

Standard(s) to which Conformity is Declared:

EN 61010-1:2001	**Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use, Part 1: General Requirements.**
EN 61326-1:2006	**Electrical Equipment for Measurement, Control and Laboratory Use - EMC Requirements – Part 1: General requirements**
EN 60825-1:1994 +A2:2001 +A1:2002	**Safety of laser products – Part 1: Equipment classification, requirements, and user's guide**
EN 55022: 1998 +A2: 2003	**Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement**

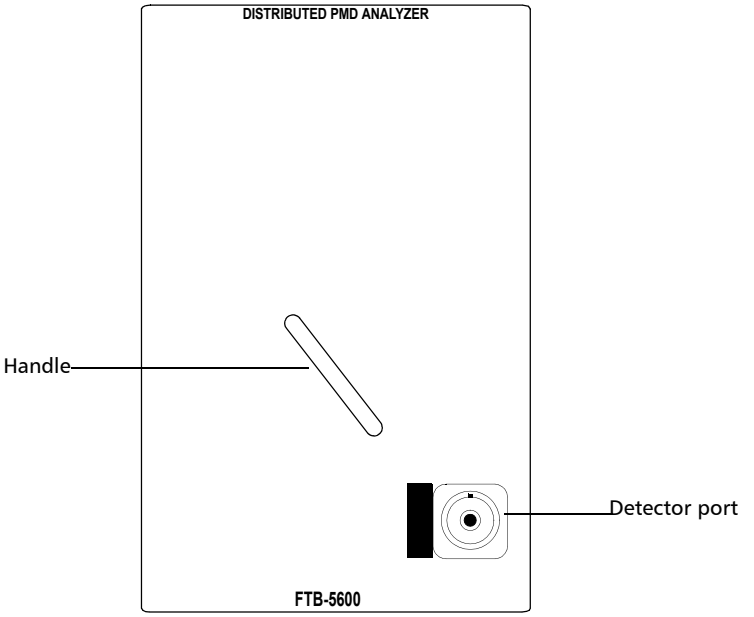
I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive and Standards.

Manufacturer
Signature:

Full Name: Stephen Bull, E. Eng
Position: Vice-President Research and Development
Address: 400 Godin Avenue, Quebec (Quebec), Canada, G1M 2K2
Date: January 09, 2009

1 Introducing the FTB-5600 Distributed PMD Analyzer

The FTB-5600 is composed of an OTDR, a tunable laser source and a polarization scrambler. It characterizes PMD along a link. Its key feature is to identify fiber sections with a strong PMD value, then enabling the correction of the link by replacing faulty sections.



The results include:

- A cumulative PMD curve and an OTDR trace
- A PMD section table that provides the PMD for each section identified by the instrument.
- An estimation table that can be used to analyze the effect of removing strong PMD sections of the link.

The result of the acquisition will be displayed as a graph, as well as several result tables to help you analyze the data better.

Basic Distributed PMD Analyzer Operation

IMPORTANT

In order to use the FTB-5600 to its most optimised level, you must have a solid knowledge on how OTDRs function.

You can make acquisitions according to three different modes:

- Quick Check
- Standard
- Advanced

Each mode is explained in *Setting up General Acquisition Parameters* on page 21.

The FTB-5600 does a series of actions in taking a measurement.

- The instrument takes an OTDR trace and displays it. This step only takes a few seconds. At this point, you should inspect the trace to see if there are any problems.
- Then, the instrument measures the SOPs. This will take more or less time depending on the accuracy and sensitivity requested. The remaining time and SOPs to measure are indicated in the status bar of the application. After measuring about 10 SOPs, you will see a temporary cumulative PMD curve.
- Once all of the SOPs are acquired, the instrument computes the actual PMD curve.

Frequently Used Terms

Some specific terms are used frequently in this user guide.

Term	Definition
APD	Avalanche photo diode.
Beating length	Length required in the fiber for the Fast Polarization to be ahead by one complete period over the Slow Polarization.
Bidirectional	A combination of two traces taken from opposite directions of a same fiber. The trace can overlap fully, partly, or not at all.
Cumulative PMD	The PMD value up to a distance in a fiber.
Depolarization	Light that is not polarized. In the case of the FTB-5600, we use this term to define zone on the fiber where the instrument cannot perform a measurement since light is entirely depolarised. For more information, see page 67.
DGD	Differential group delay.
Estimation table	Table used to estimate the PMD value of a link by changing values of target strong PMD sections.
FUT	Fiber under test
OTDR	Optical time domain reflectometer.
PBS	Polarization beam splitter
PMD	Polarisation mode dispersion.
PMD coefficient	Represents the PMD characteristics of one particular length of the fiber. Since PMD adds to the square, its unit is typically calculated in picoseconds per square root of kilometer.
PMD resolution	Sets the minimum PMD value to be measured on the link.

Term	Definition
PMD scale	Sets the best scale to measure a PMD of this value.
PMD section	The PMD value of a fiber section
Pulse width	Width of the OTDR pulse, in nanoseconds, used to measure the link. A longer pulse allows you to probe further along the fiber, but results in a lower resolution. A shorter pulse width provides higher resolution , but a smaller distance range.
RS-POTDR	Random-scrambling tuneable polarization-sensitive OTDR
Sensitivity	Sets the electronic sensitivity.
SOP	State of polarisation. Here, SOP has a broader sense: it means a group of OTDR traces taken at different frequencies, but with the same SOP. The SOP is the unit that is used to compute the distributed PMD curve.
SOA	Semiconductor optical amplifier

Conventions

Before using the product described in this manual, you should understand the following conventions:

WARNING

Indicates a potentially hazardous situation which, if not avoided, could result in *death or serious injury*. Do not proceed unless you understand and meet the required conditions.

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in *minor or moderate injury*. Do not proceed unless you understand and meet the required conditions.

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in *component damage*. Do not proceed unless you understand and meet the required conditions.

IMPORTANT

Refers to information about this product you should not overlook.

2 Safety Information

WARNING

Do not install or terminate fibers while a light source is active. Never look directly into a live fiber and ensure that your eyes are protected at all times.

WARNING

Use of controls, adjustments and procedures for operation and maintenance other than those specified herein may result in hazardous radiation exposure or impair the protection provided by this unit.

Your instrument is a Class 1 laser product in compliance with standards IEC60825-1: 2001, 2007 and 21CFR1040.10. Laser radiation may be encountered at the output port.

The following label indicates that a product contains a Class 1 source:

Note: *Label shown for information purposes only. It is not affixed to your product.*

3 Getting Started with your FTB-5600

Inserting and Removing Test Modules

CAUTION

Never insert or remove a module while the FTB-500 is turned on. This will result in immediate and irreparable damage to both the module and unit.

WARNING

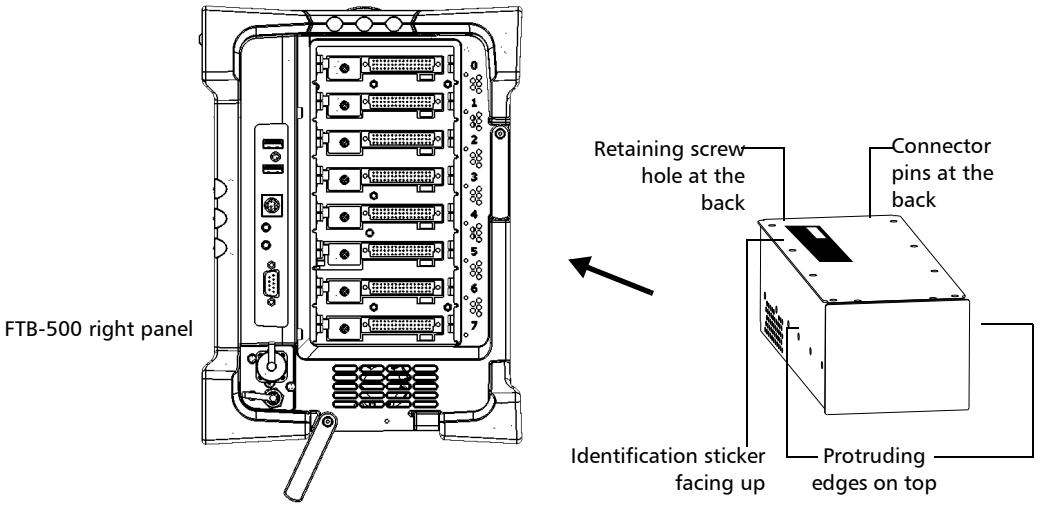
When the laser safety LED () is flashing on the FTB-500, at least one of your modules is emitting an optical signal. Please check all modules, as it might not be the one you are currently using.

To insert a module into the FTB-500:

1. Exit ToolBox and turn off your unit.
2. Position the FTB-500 so that its right panel is facing you.

3. Take the module and place it so that the connector pins are at the back, as explained and shown below.

Identification sticker must be facing up and connector pins at the right of the retaining screw hole.



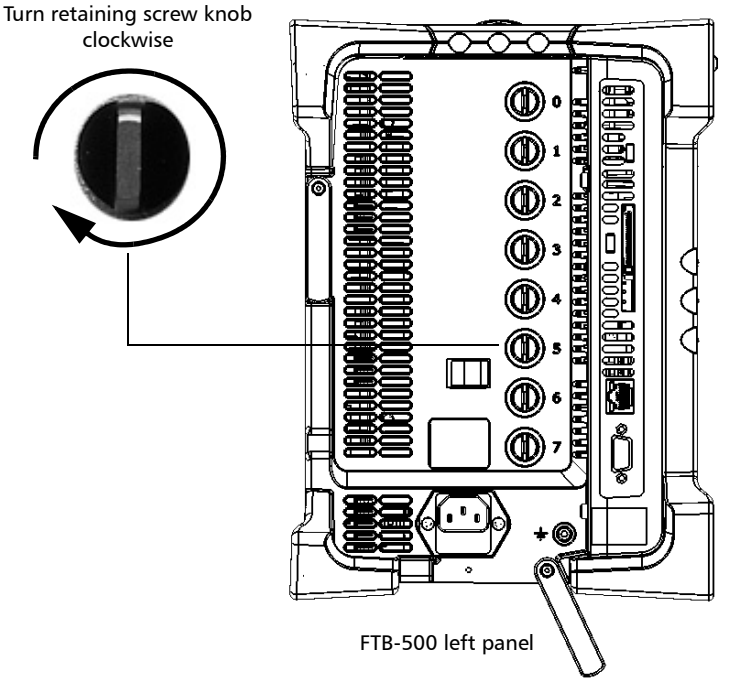
4. Insert the protruding edges of the module into the grooves of the receptacle's module slot.

5. Push the module all the way to the back of the slot, until the retaining screw makes contact with the receptacle casing.

6. Place the FTB-500 so that its left panel is facing you.

7. While applying slight pressure to the module, turn the retaining screw clockwise until it is tightened.

This will secure the module into its “seated” position.



When you turn on the unit, the startup sequence will automatically detect the module.

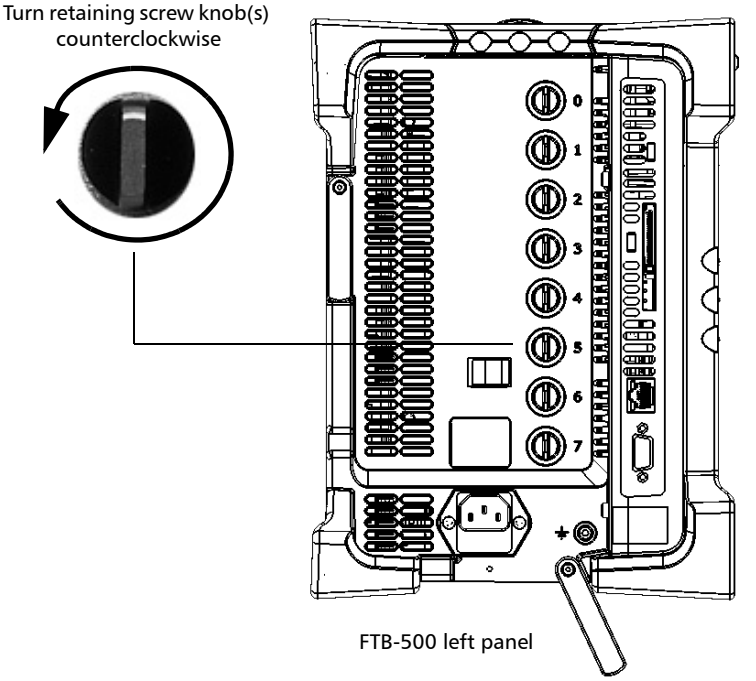
To remove a module from the FTB-500:

1. Exit ToolBox and turn off your unit.

2. Position the FTB-500 so that the left panel is facing you.

3. Turn the retaining screw counterclockwise until it stops.

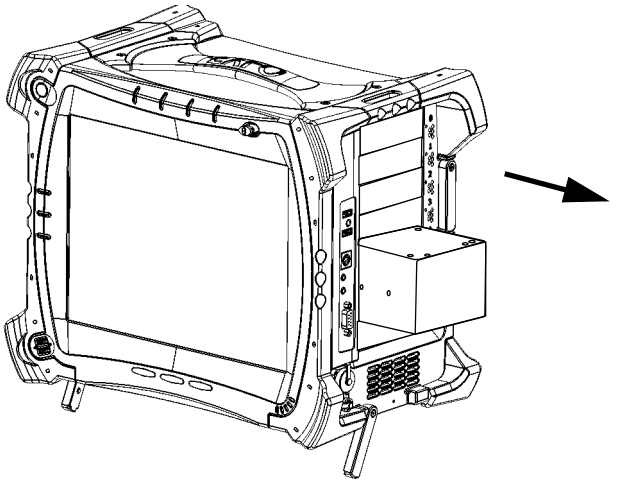
The module will be slowly released from the slot.



FTB-500 left panel

4. Place the FTB-500 so that the right panel is facing you.

5. Hold the module by its sides or by the handle (*NOT by the connector*) and pull it out.



Starting the Distributed PMD Analyzer Application

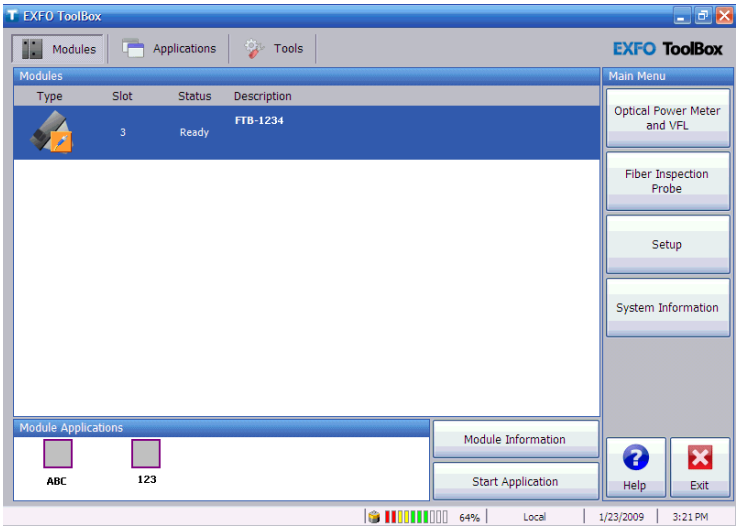
Your FTB-5600 Distributed PMD Analyzer module can be configured and controlled from its dedicated ToolBox application.

Note: *For details about ToolBox, refer to the* FTB-500 *user guide.*

To start the application:

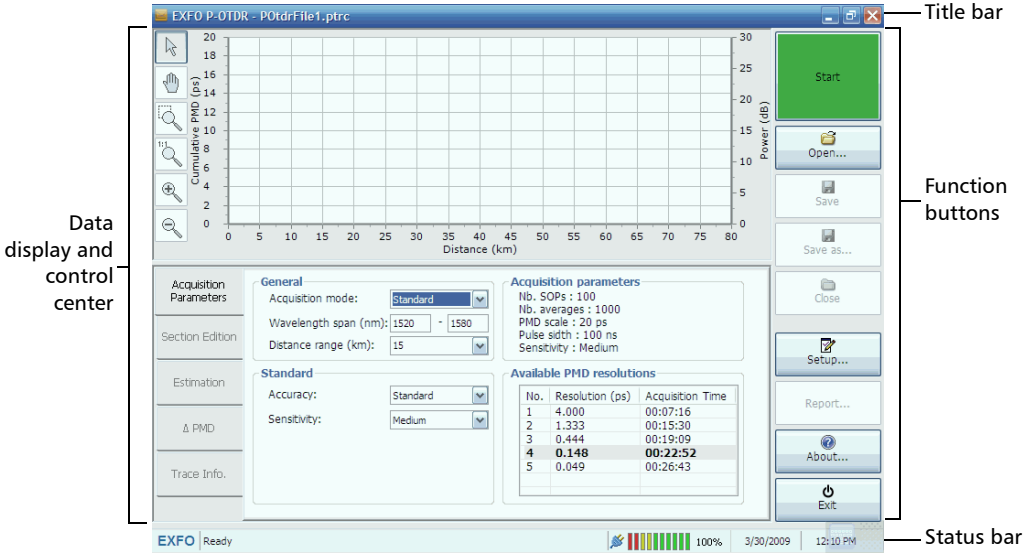
1. From the main window, select the module to use.

   It will turn blue to indicate that it is highlighted.



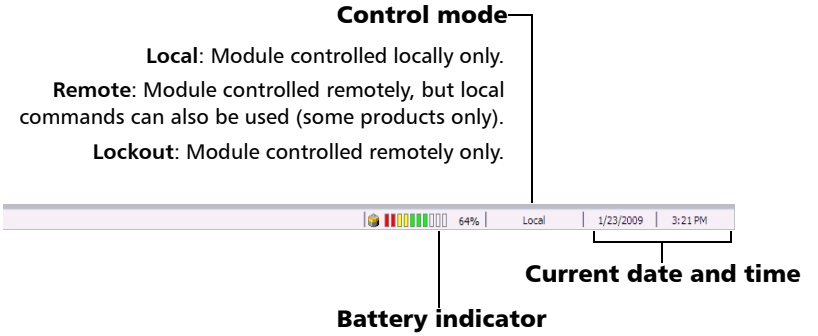
2. Click the corresponding button in the **Module Applications** box.

The main window (shown below) contains all the commands required to control the Distributed PMD Analyzer:



Status Bar

The status bar, located at the bottom of the main window, identifies the current operational status of the FTB-5600 Distributed PMD Analyzer.



Exiting the Application

Closing any application that is not currently being used helps freeing system memory.

To close the application from the main window:

Click ☒ in the top right corner of the main window.

OR

Click the **Exit** button located at the bottom of the function bar.

4 Setting up and Operating your Distributed PMD Analyzer

IMPORTANT

In order to use the FTB-5600 to its most optimised level, you must have a solid knowledge on how OTDRs function. This includes:

- **Interpreting OTDR traces**
- **Understanding the effect of the pulse on a trace**
- **Understanding the contents of an event trace**
- **Manipulating events on a trace**

The instructions and theory in this user documentation take into account that such notions are already known by you.

Cleaning and Connecting Optical Fibers

IMPORTANT

To ensure maximum power and to avoid erroneous readings:

- **Always inspect fiber ends and make sure that they are clean as explained below before inserting them into the port. EXFO is not responsible for damage or errors caused by bad fiber cleaning or handling.**
- **Ensure that your patchcord has appropriate connectors. Joining mismatched connectors will damage the ferrules.**

To connect the fiber-optic cable to the port:

1. Inspect the fiber using a fiber inspection microscope. If the fiber is clean, proceed to connecting it to the port. If the fiber is dirty, clean it as explained below.
2. Clean the fiber ends as follows:
   - **2a.** Gently wipe the fiber end with a lint-free swab dipped in isopropyl alcohol.
   - **2b.** Use compressed air to dry completely.
   - **2c.** Visually inspect the fiber end to ensure its cleanliness.

3. Carefully align the connector and port to prevent the fiber end from touching the outside of the port or rubbing against other surfaces.

If your connector features a key, ensure that it is fully fitted into the port's corresponding notch.

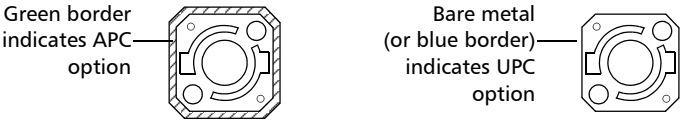
4. Push the connector in so that the fiber-optic cable is firmly in place, thus ensuring adequate contact.

If your connector features a screwsleeve, tighten the connector enough to firmly maintain the fiber in place. Do not overtighten, as this will damage the fiber and the port.

Note: *If your fiber-optic cable is not properly aligned and/or connected, you will notice heavy loss and reflection.*

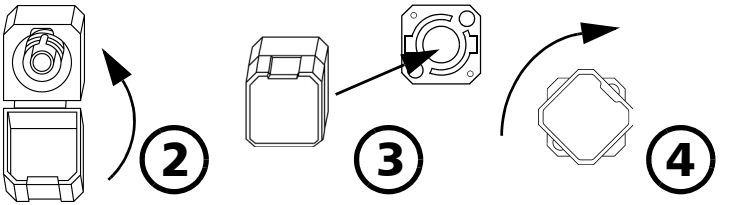
Installing the EXFO Universal Interface (EUI)

The EUI fixed baseplate is available for connectors with angled (APC) or non-angled (UPC) polishing. A green border around the baseplate indicates that it is for APC-type connectors.



To install an EUI connector adapter onto the EUI baseplate:

1. Hold the EUI connector adapter so the dust cap opens downwards.



2. Close the dust cap in order to hold the connector adapter more firmly.

3. Insert the connector adapter into the baseplate.

4. While pushing firmly, turn the connector adapter clockwise on the baseplate to lock it in place.

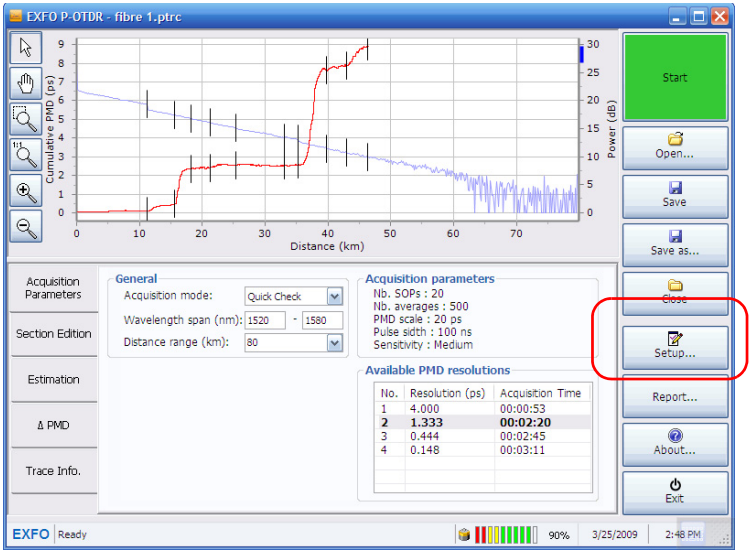
Setting up General Acquisition Parameters

The general acquisition parameters influence how the acquisition occurs.

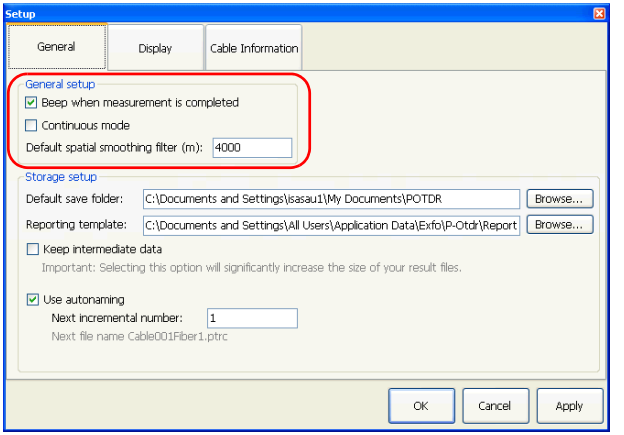
- You can select whether the unit beeps after each measurement or not.
- You can set the acquisition to be continuous, or requiring that you start each measurement manually.
- You can set the default spatial smoothing filter, in meters. The spatial smoothing filter helps improving the measurement results in filtering the cumulative PMD curve. The default value is 4000 m. Increase this value if the PMD cumulative curve is appropriate, but wavy, for example. Decrease this value if you are interested in seeing where the PMD begins to increase. You can find more information on the spatial smoothing filter in *Use an Appropriate Spatial Smoothing Filter Value* on page 129.

To change the general acquisition parameters:

1. From the main window, press **Setup**.



2. Select the **General** tab.



3. Modify the parameters as desired under **General setup**.

4. Press **Apply** to use the new settings, or **OK** to use the new settings and close the window.

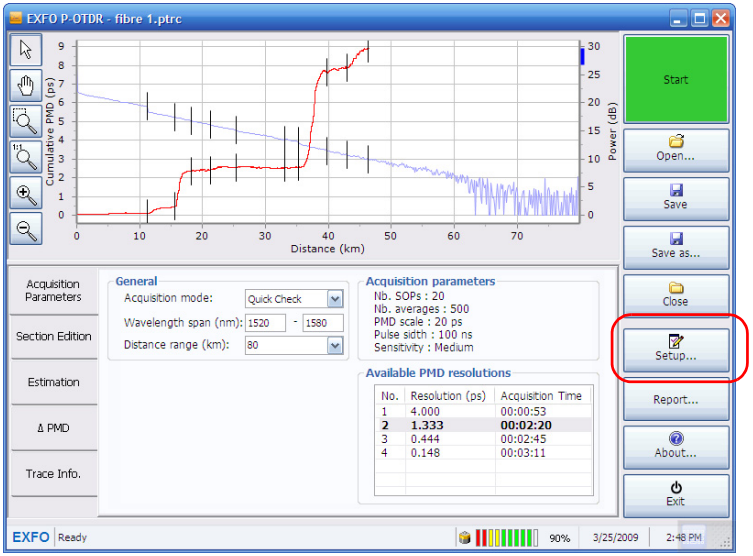
Setting up the Graph Display

The graph display parameters will help you improve how result graphs are displayed.

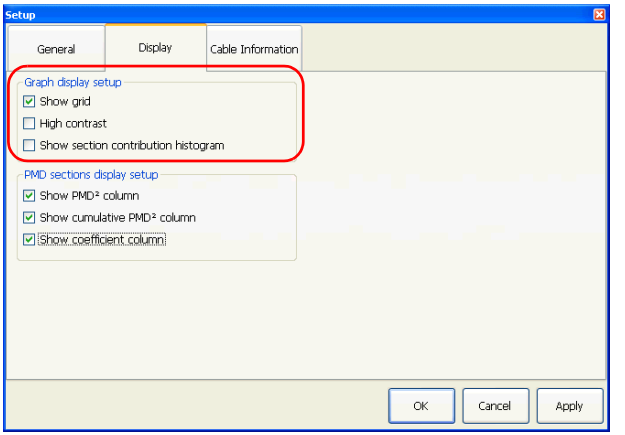
- You can display or hide the grid.
- You can use the high contrast view if the lighting quality prevents you from seeing the graph properly (glare from the sun, darkness).
- You can show or hide the section contribution histogram. This histogram is a graphic representation of the contents of the **Contr.%** column in the section table.

To change the graph display parameters:

1. From the main window, press **Setup**.



2. Select the **Display** tab.



3. Modify the parameters as desired under **Graph display setup**.
4. Press **Apply** to use the new settings, or **OK** to use the new settings and close the window.

Setting up Storage Options

The FTB-5600 will automatically save the acquisition files during the test. You can set where the unit saves the data, select which template is used for creating reports, and you can use an autonaming scheme to facilitate and speed up your work.

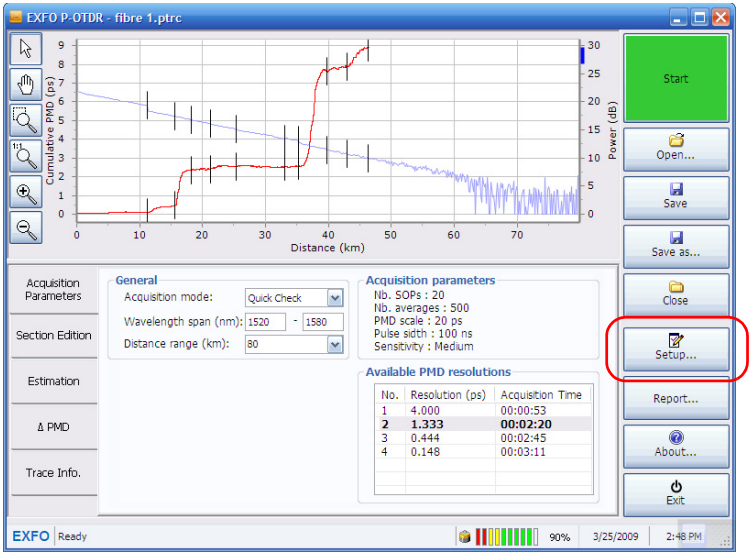
You can also decide to keep the intermediate data while performing acquisitions. This option should be used when there is a problem with your unit or a measurement. Once you have acquired this data, which represents all of the actions done by the unit when performing the test, you can take the resulting file and send it to EXFO for troubleshooting purposes.

IMPORTANT

Keeping the intermediate data will increase the size of the result file in a significant manner.

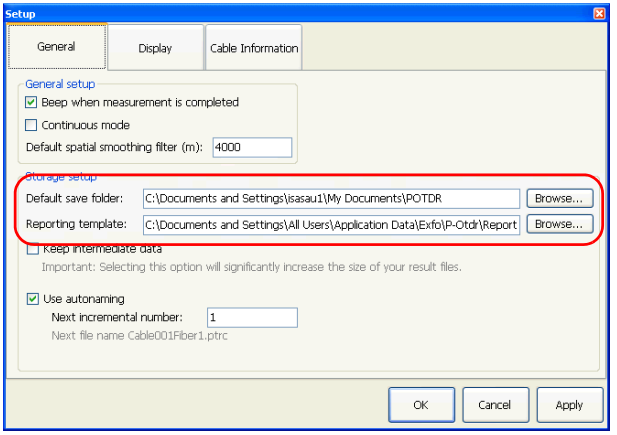
To set up the storage options:

1. From the main window, select **Setup**.

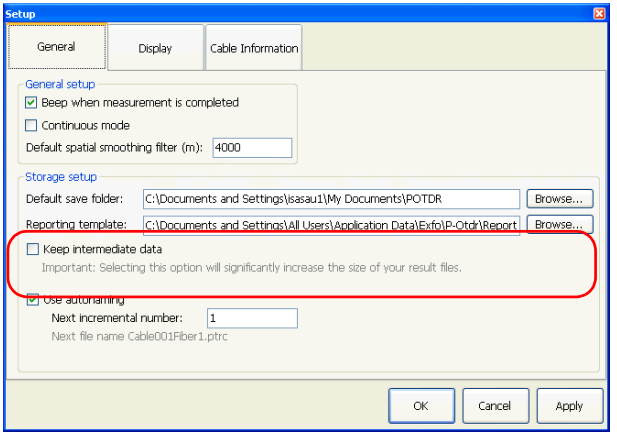


2. Select the **General** tab.

3. Under **Storage setup**, enter the paths for the default save folder and the reporting template. You can also use the **Browse** button to open a standard navigation window.



4. If desired, select the **Keep intermediate data** option.

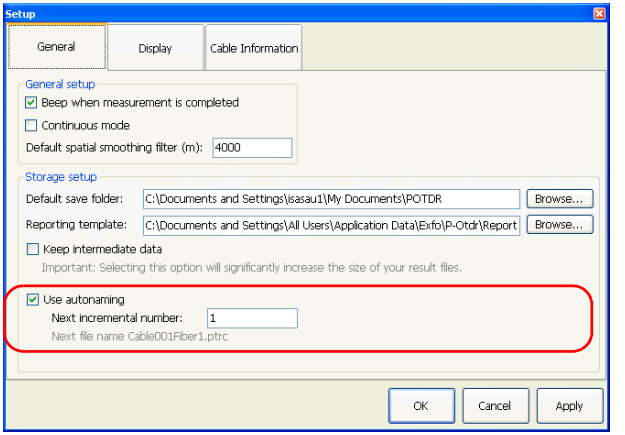


5. If desired, activate the autonaming feature. If you want the incrementation to start on a specific number, enter it in the **Next incremental number** box. You will see a preview of the next file name at the bottom of the window.

Note: *If your acquisition is set to continuous, the autonaming feature is automatically selected and you cannot change this setting.*

IMPORTANT

If you had previously saved files that have the same name as those created by the autonaming feature, they will be replaced without any notification.



6. Press **Apply** to use the new settings, or **OK** to use the new settings and close the window.

Displaying PMD-Related Columns in the Main Window

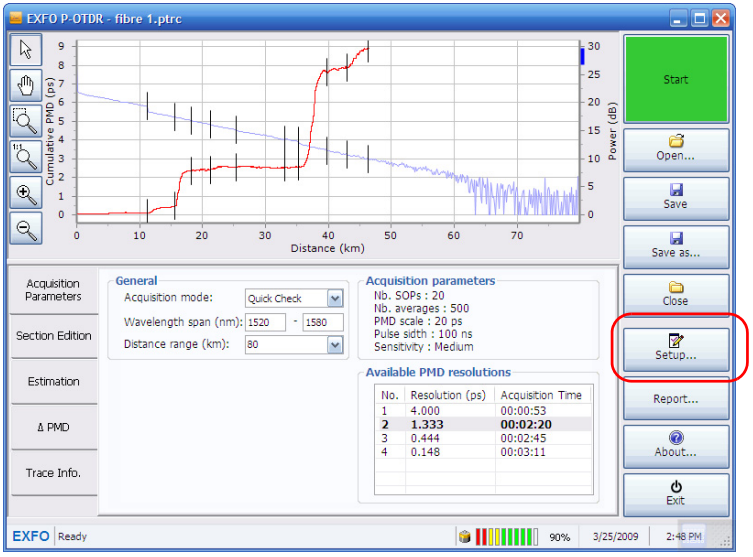
You can decide to hide or display the following columns in the main window:

- PMD^2
- Cumulative PMD^2
- PMD coefficient

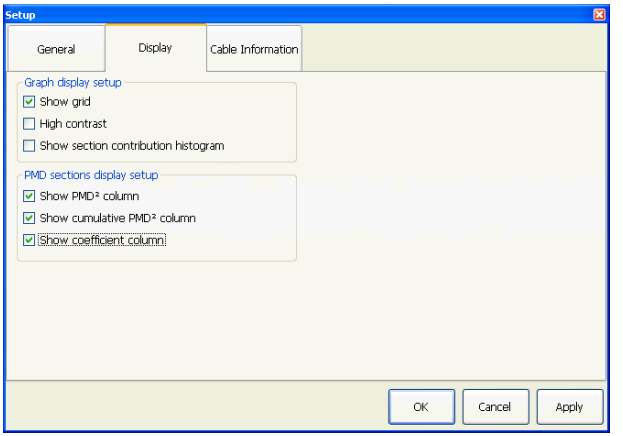
Note: *If you decide to hide or display those columns, the change will take effect immediately in the result tabs*

To display PMD-related columns in the main window:

1. From the main window, press **Setup**.



2. Select the **Display** tab.



3. Under **PMD sections display setup**, select which column or columns you want to display.

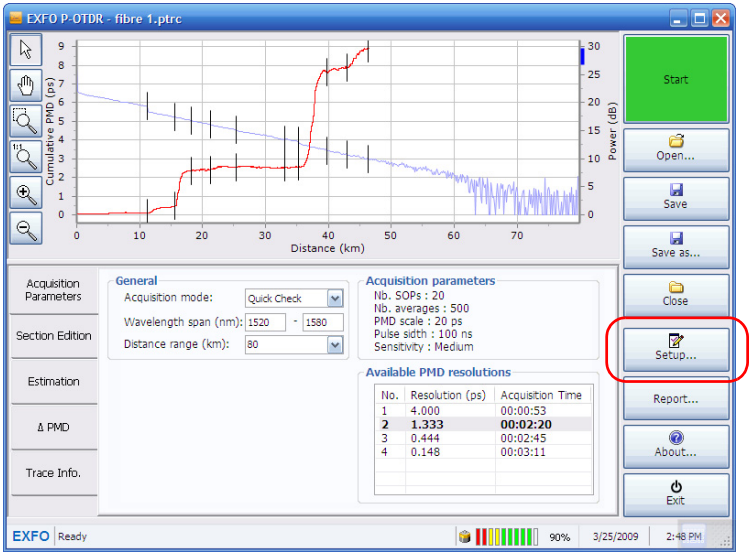
4. Press **Apply** to use the new settings, or **OK** to use the new settings and close the window.

Setting up Cable Information

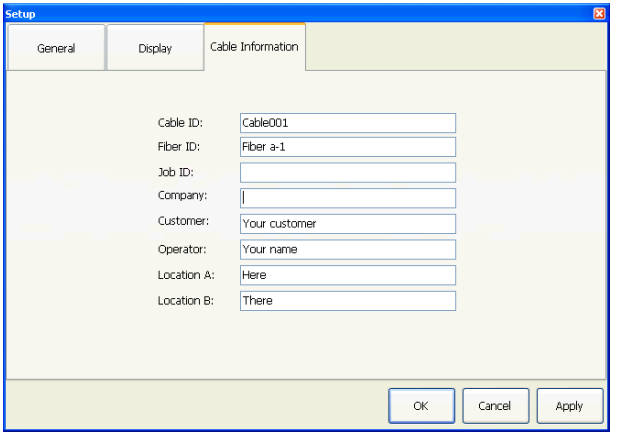
The cable information is useful to help you differentiate your various acquisitions. It will also appear in reports you generate for your acquisitions.

To set the cable information:

1. From the main window, select **Setup**.



2. Select the **Cable Information** tab.



3. Enter the information as needed.

4. Press **Apply** to confirm the information, or **OK** to confirm the information and close the window.

Performing an Acquisition

IMPORTANT

When measuring PMD, it is very important that the launch fiber is not moved.

You can perform the test according to three acquisition modes:

- *Quick Check:* This mode is used to obtain a fast overview of a link. All you have to do is set the distance range for the link. To perform a Quick Check, see *Performing a Quick Check Acquisition* on page 35.
- *Standard:* This mode is the general test mode. All you have to set is the accuracy and sensitivity levels. This mode is selected by default when you open the application. To perform a standard acquisition, see *Performing a Standard Acquisition* on page 37.
- *Advanced:* This mode is used to perform an optimized acquisition. You will have to set all of the parameters individually. This acquisition will take more time to perform, but will return more details and can be fully optimized. To perform an advanced acquisition, see *Performing an Advanced Acquisition* on page 41.

The FTB-5600 does a series of actions in taking a measurement.

- The instrument takes an OTDR trace and displays it. This step only takes a few seconds. At this point, you should inspect the trace to see if there are any problems.
- Then, the instrument measures the SOPs. This will take more or less time depending on the accuracy and sensitivity requested. The remaining time and SOPs to measure are indicated in the status bar of the application. After measuring about 10 SOPs, you will see a temporary cumulative PMD curve.
- At this point, considering that the overall measurement process is quite long, EXFO strongly recommends that you make a general inspection of the OTDR trace to verify that the instrument is properly connected and that the FUT is OK.
- Once all of the SOPs are acquired, the instrument computes the actual PMD curve.

Performing a Quick Check Acquisition

The main purpose of the quick check is to have an estimate of the cumulative PMD of the link to select the appropriate PMD scale.

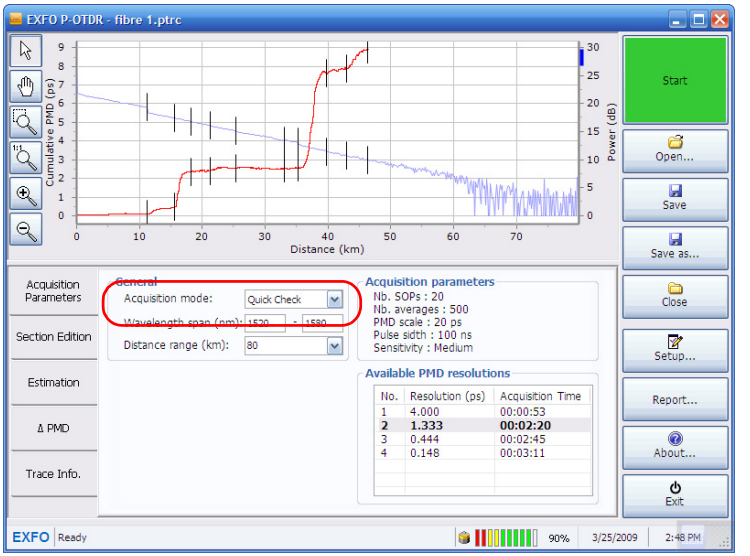
Using the Quick Check OTDR trace and cumulative PMD curve, you can verify the following:

- The injection level: it should be within the injection level accepted range, as it is the case with an OTDR. If it is not, correct the connection at the instrument. This will improve the dynamic range.
- The link length: the range value may be updated with the link length seen on the trace. This reduces the size of the file and accelerates both processing and acquisition times.
- The link PMD maximum value could be used to set the PMD scale of the advanced settings. This may have a major impact on the acquisition time.
- Where the PMD trace ends. If it ends very far from the end of the link, then the number of averages could be increased to improve the dynamic range.

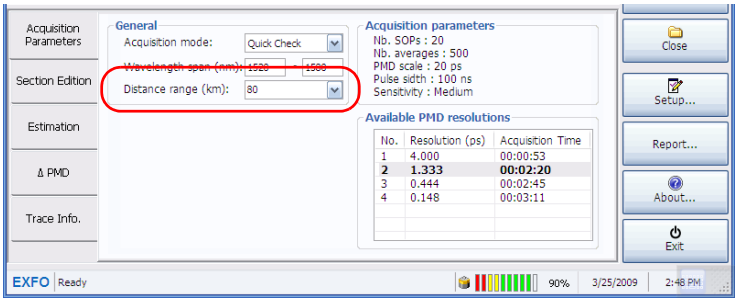
This mode uses a low number of SOPs, therefore the measurement will not be accurate. You should not use this acquisition mode to characterize entire links. The default PMD scale for this mode is 20 ps.

To perform a Quick Check acquisition:

1. From the main window, under **General**, select the Quick Check acquisition mode.



2. Set the distance range, in kilometers, from the list of available values. You can also type in the value directly. Reducing the range to the part of the link that you want to measure will increase measurement speed and decrease the resulting file size. If you do not know the length of the link, you can rely on the OTDR trace to estimate it.



3. Press **Start**.

   The acquisition starts. You can see the remaining time in the status bar.

Performing a Standard Acquisition

The acquisitions are more optimized for characterizing the link correctly rather than for the acquisition time. The default PMD scale for this mode is 20 ps. EXFO recommends setting the accuracy to the standard level and the sensitivity to the medium level for an acquisition of about 30 minutes.

The *accuracy* of the measurement changes the number of SOPs and residual PMD. A higher level of SOPs will yield a more accurate result, but longer acquisition time.

Accuracy	Number of SOPs	PMD Resolution (fs)
Low	50	1333
Medium	100	148
High	200	50

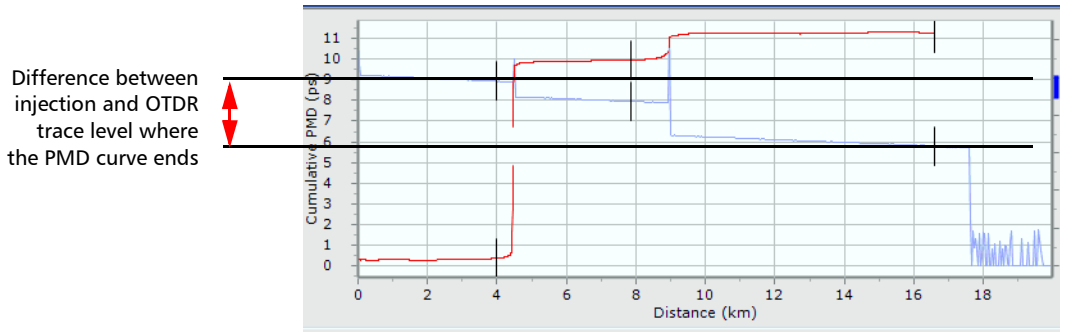
The *sensitivity* of the measurement allows you to increase the PMD measurement range. A greater sensitivity increases the number of averages and will take longer to be achieved.

Sensitivity	Number of Averages	Electronic Sensitivity
Low	500	Low APD gain
Medium	1000	High APD gain
High	2000	High APD gain

To improve the dynamic range for your acquisition, consider the following:

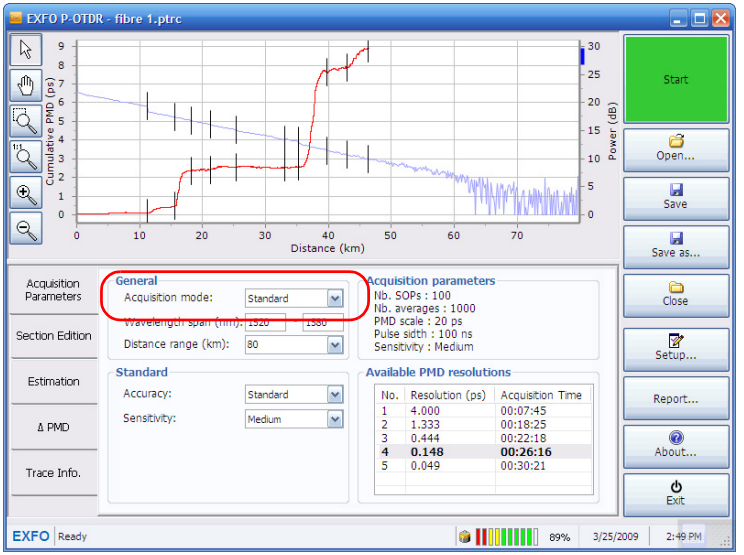
- For less than 13 dB, put the sensitivity to *low*. This means an acquisition of about 15 minutes with three resolutions.
- Setting the sensitivity to *medium* will improve the dynamic range and means an acquisition of about 30 minutes with three resolutions.
- Setting the sensitivity to *high* will give you the optimal dynamic range and means an acquisition of about 1 hour with three resolutions.

Note: *You can obtain the dynamic range of the trace by subtracting the backscatter level at the fiber end from the injection level accepted range value.*

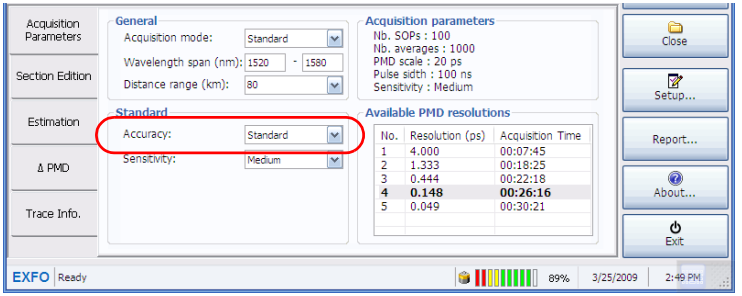


To perform a standard acquisition:

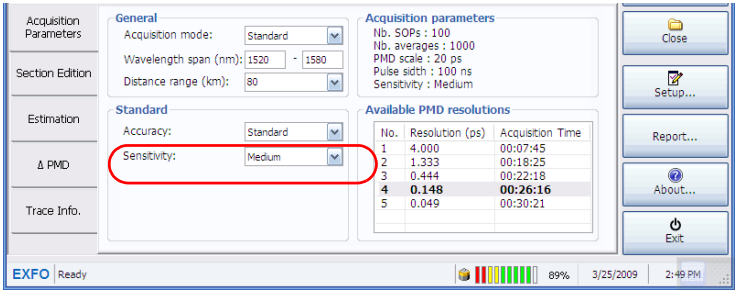
1. From the main window, under **General**, select the Standard acquisition mode.



2. Set the accuracy of the measurement by selecting a value in the list.

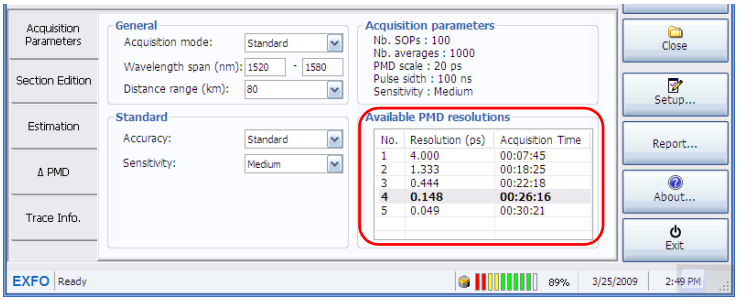


3. Set the sensitivity of the measurement by selecting a value in the list.



4. Select the PMD resolution that can best fit the minimum measurable value for your PMD scale.

Note: *The PMD resolution will influence the acquisition time; the estimated value is next to each scale.*



5. Press **Start**.

The acquisition starts. You can see the remaining time in the status bar.

Performing an Advanced Acquisition

The advanced acquisition parameters will help you perform a more accurate test. For more information on setting the parameters to optimize your acquisition, see *Optimizing Measurements* on page 121.

- The number of polarization states (SOP) used will change the accuracy for your acquisition as it increases. However, it will also increase the acquisition time accordingly.

  EXFO recommends a measurement of at least 100 SOPs in order to have a significant cumulative PMD curve. A value of 50 SOPs will return a crude measurement. The most accurate measurements will be done with a number of SOPs ranging from 400 to 1000.

- The number of averages sets each individual OTDR trace number of averages. These OTDR traces are used to build the cumulative PMD curve. A higher number of averages decreases the noise and increases the acquisition time.

  EXFO recommends a value of 500 averages; use more if the measurement range is too small. A value below 500 may affect the precision of the acquisition estimated time.

- The PMD scale sets the target value of the cumulative PMD of the FUT to be measured. If you already know the PMD value of the FUT, select the closest value in the list. You can also crudely evaluate this value by performing a Quick Check (see *Performing a Quick Check Acquisition* on page 35 for details). If you see that the PMD curve is very wavy and is at the same level as the PMD resolution, the PMD scale value is too high.

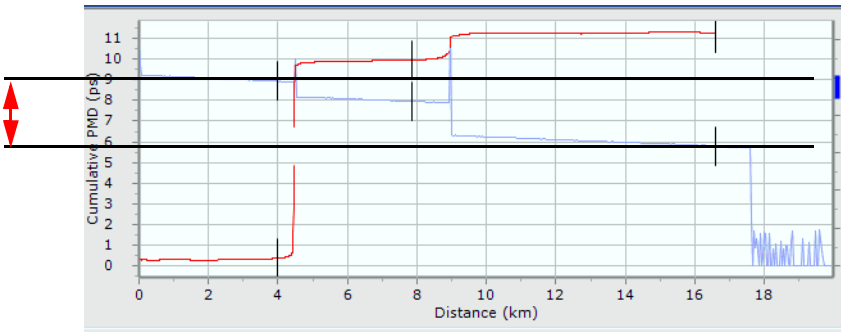
- The pulse width sets the length of the OTDR pulse used to characterize the PMD cumulative curve. Increasing the value also increase acquisition time. EXFO recommends using a pulse width of 100 ns. If more dynamic range is required and that there are no depolarized sections, you can use a pulse width of up to 275 ns. If there are depolarized sections, using a lower value such as 50 ns may help.

➤ The sensitivity parameter sets the electronic APD gain. You should use the high setting unless you are interested only in the very beginning of the link. The sensitivity of the measurement is dependant on the PMD range. A greater sensitivity increases the number of averages and will take longer to be achieved. Consider the following to improve your dynamic range.

Sensitivity	Number of Averages to Select
Low	500
Medium	1000
High	2000

Note: *You can obtain the dynamic range of the trace by subtracting the backscatter level at the fiber end from the injection level accepted range value.*

Difference between injection and OTDR trace level where the PMD curve ends

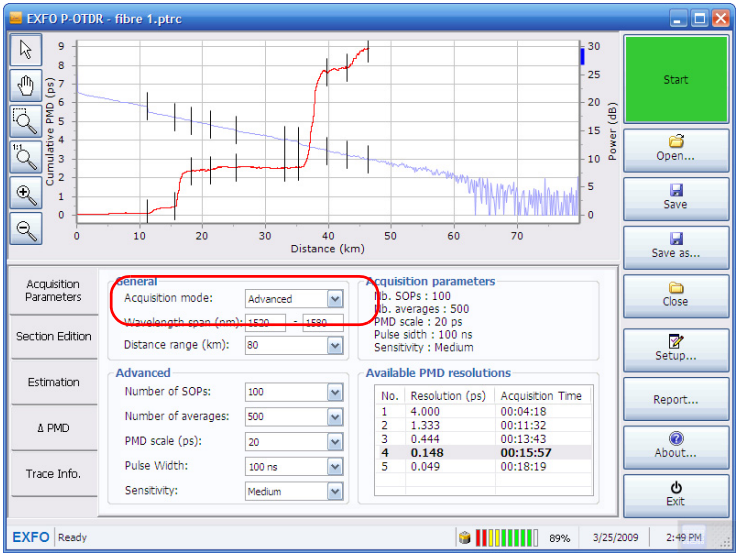


➤ The PMD resolution is the minimum value to be measured. EXFO recommends setting this value to the lowest value of interest for your testing purposes. A smaller PMD resolution signifies a larger number of PMD steps and increases acquisition time.

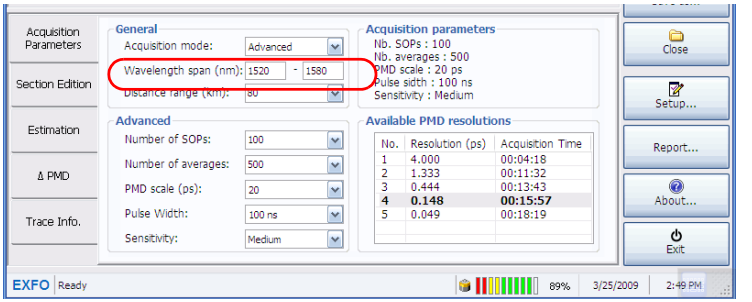
For rough measurements in links with high PMD, you should use a value between 0.4 and 1 ps. For low PMD measurements, use a value around 50 ps and at least 100 SOPs. For faster measurements of small PMD values, use a lower setting, such as 2 ps.

To perform an advanced acquisition:

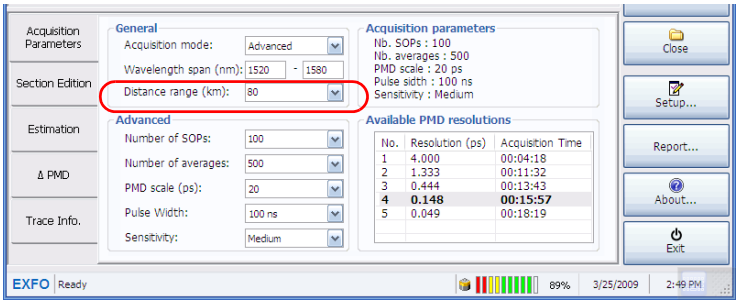
1. From the main window, under **General**, select the Advanced acquisition mode.



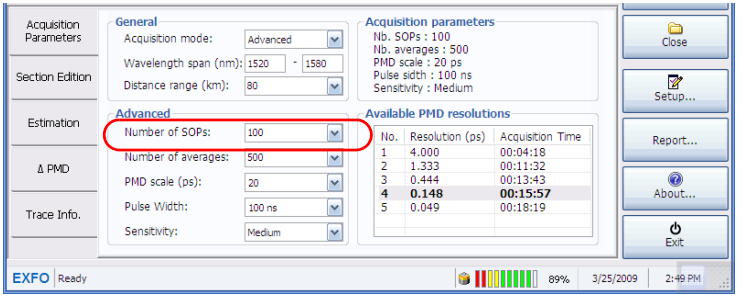
2. Set the wavelength span for your test. The default range is 1520 nm to 1580 nm. EXFO does not recommend changing this range unless you want to perform a very specific test.



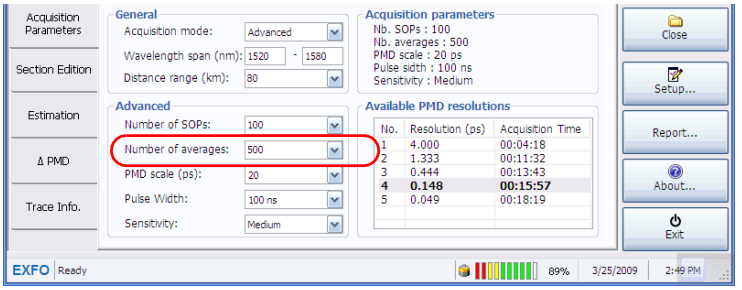
3. Set the distance range, in kilometers, from the list of available values, or you can enter your own manually. Reducing the range to the part of the link that you want to measure will increase measurement speed and decrease the resulting file size. If you do not know the length of the link, you can rely on the OTDR trace to estimate it.



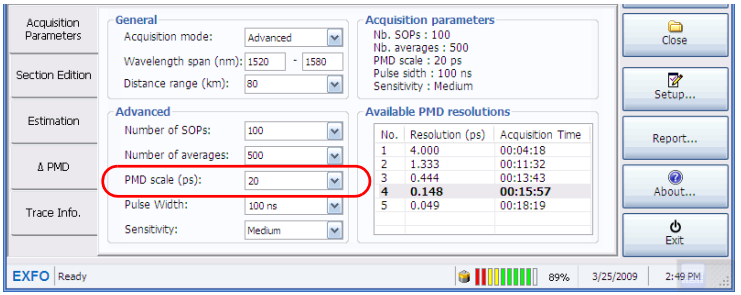
4. Under **Advanced**, select the number of SOPS from the list of available values. You can also type in a value directly.



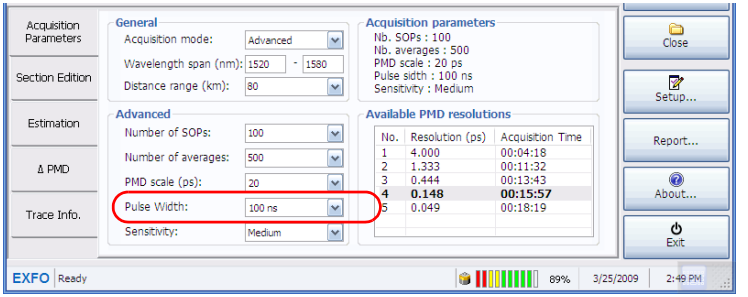
5. Select the number of averages for the measurement. You can also type in a value directly.



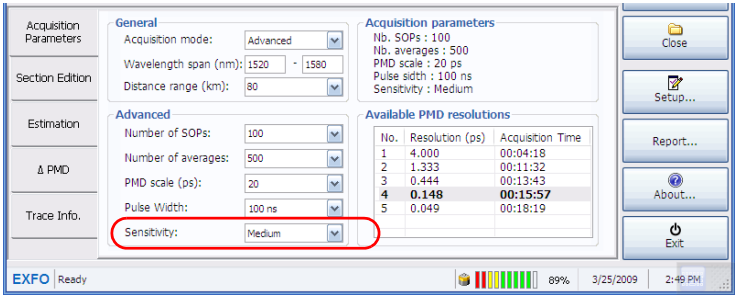
6. Select the PMD scale, in ps.



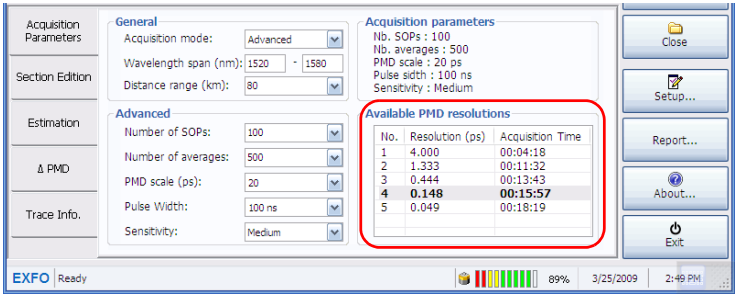
7. Select the pulse width, in ns



8. Select the sensitivity level.



9. Select the appropriate PMD resolution from the list.



A summary of the parameters is displayed on-screen.

10. Press **Start**.

The acquisition starts. You can see the remaining time and number of SOPs in the status bar.

Using the Bidirectional File Creator

Since PMD accumulates in quadratic manner, the higher the PMD, the more difficult it is to measure weak PMD variations. Using a measurement coming from each end of the link you want to characterize and combining the two measurements into one bidirectional trace file can help you improve the precision of the measurement all over the link.

When measuring links that are too long for the dynamic range of the unit, creating a bidirectional trace by combining the traces coming from each end doubles the effective measurement range.

The files can therefore overlap fully, partly, or not overlap at all.

Note: *You cannot use a bidirectional file you have already created to create a new bidirectional file.*

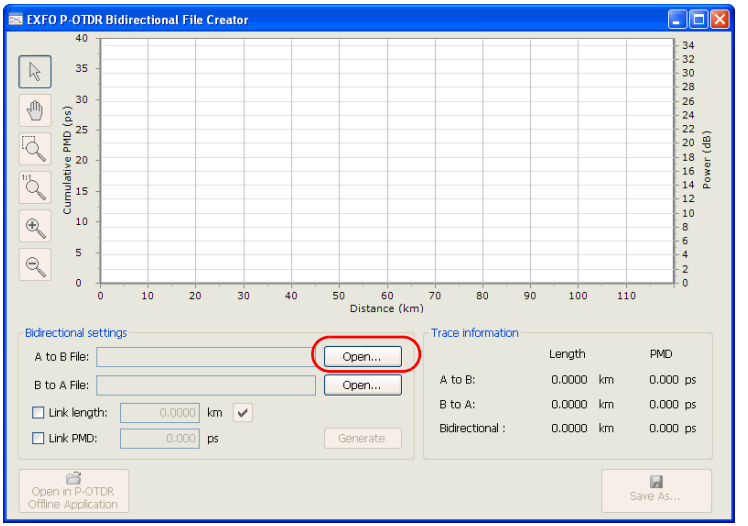
To create a bidirectional file:

1. From Windows, select **start**, then **All Programs > EXFO > Programs**.

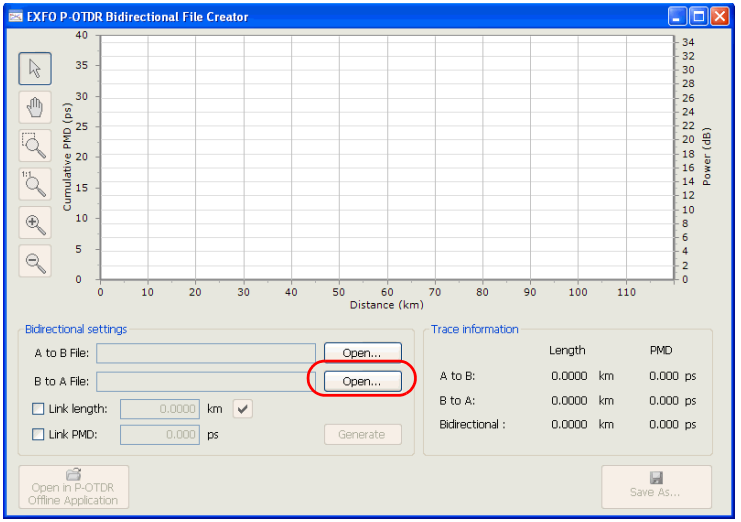
   OR

   From ToolBox, select the **Applications** tab, then **P-OTDR Bidirectional File Creator**.

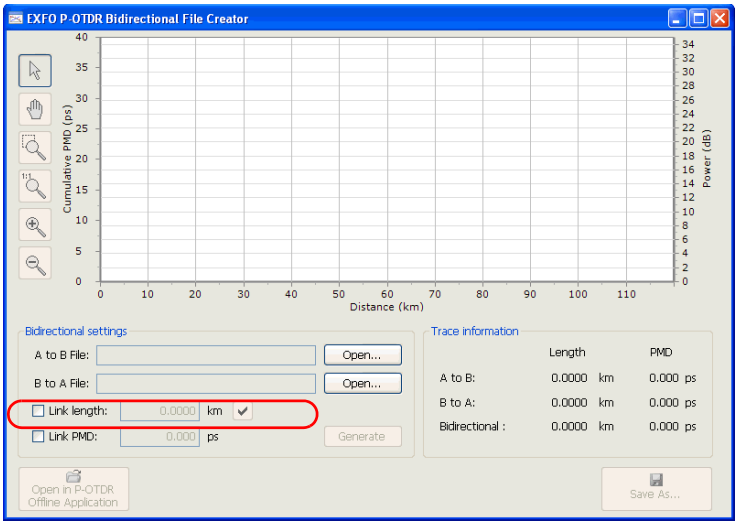
2. Select the trace file you want to use for the A -> B side by using the corresponding **Open** button.



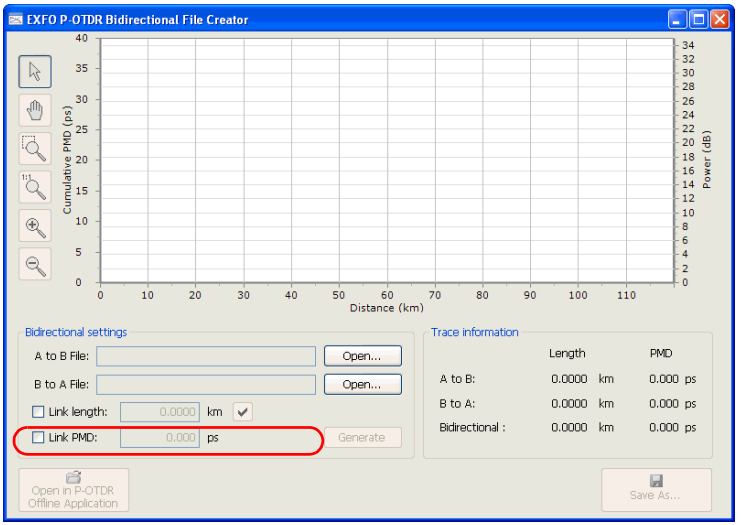
3. Select the trace file you want to use for the B -> A side by using the corresponding **Open** button.



4. If the two traces do not allow the automatic calculation of the length of the link (for example, they do not cover the same distance), or if you want to specify a length yourself, select the corresponding option, then enter the value you want.

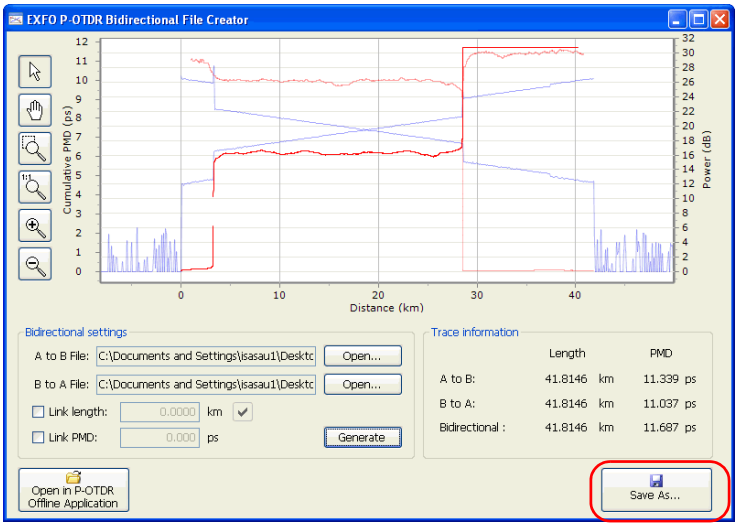


5. If you want to specify an estimation of the PMD on the link, select the corresponding option.



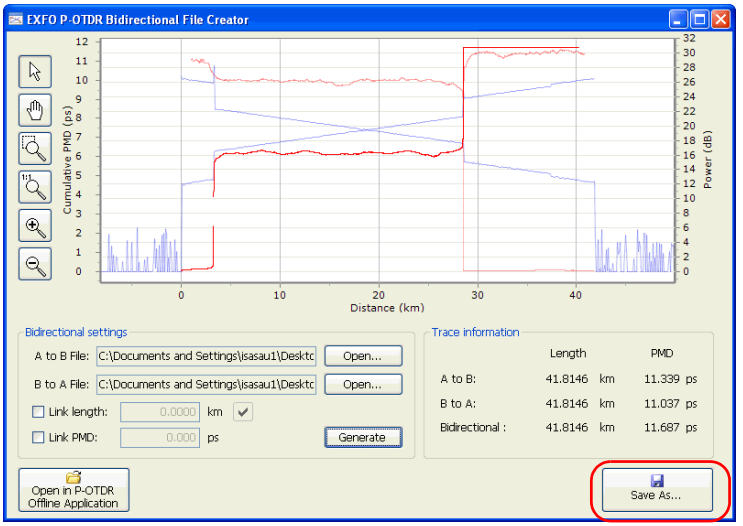
6. Click **Generate** to start the bidirectional file creation.

The resulting traces appear on-screen once the application is done creating the file.



To save the created bidirectional trace:

1. Select **Save as**, then select a name and location for your file.

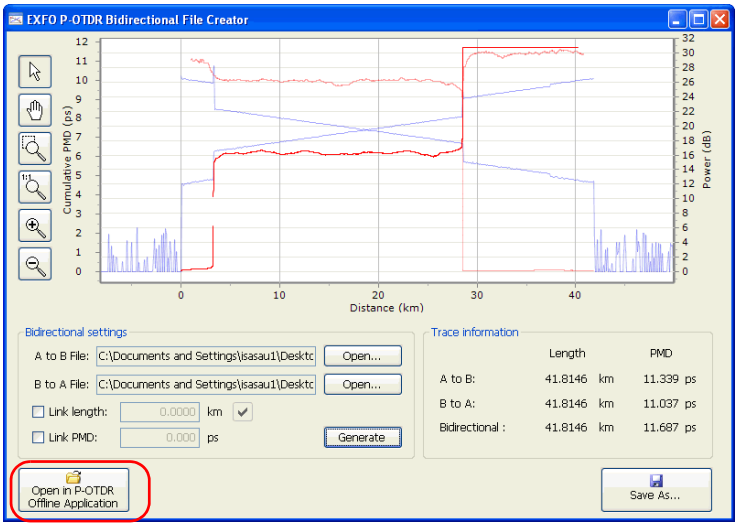


2. Select **Save**.

Note: *For information on using the zooming tools, see* Using Zoom Controls *on page 62.*

To open the created trace in the P-OTDR application to analyze it:

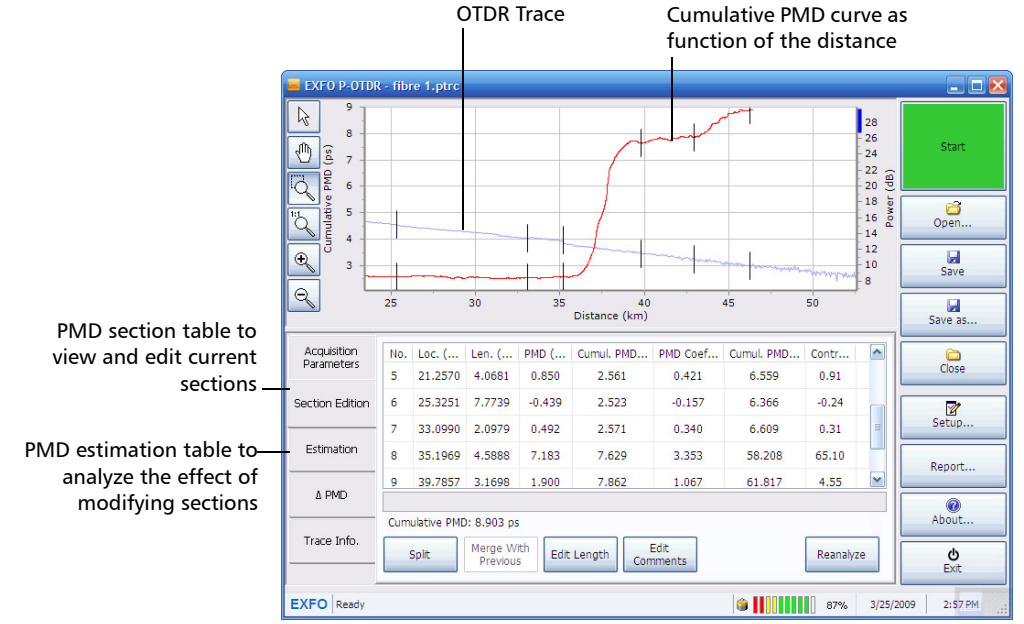
Once the trace was created and saved, select **Open in P-OTDR**.



Note: *A bidirectional file is always identified as such in the title bar of the P-OTDR application window.*

5 Managing Results

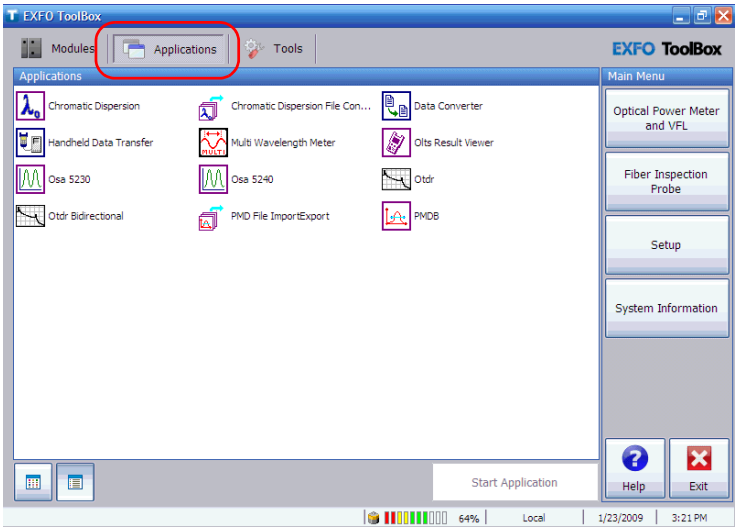
Once the acquisition is complete, you can see data appear on-screen.



You can perform result analyses directly in the FTB-5600, but you can also use the offline application that you can access through ToolBox. The offline application is identical to the online application, except that you cannot make acquisitions with it; therefore, you will see that the **Start** button, as well as the **Acquisition Parameters** are disabled.

To access the offline application:

1. From ToolBox, select the **Applications** tab.



Note: *Depending on which applications are installed on your platform, the* ***Applications*** *tab may look different.*

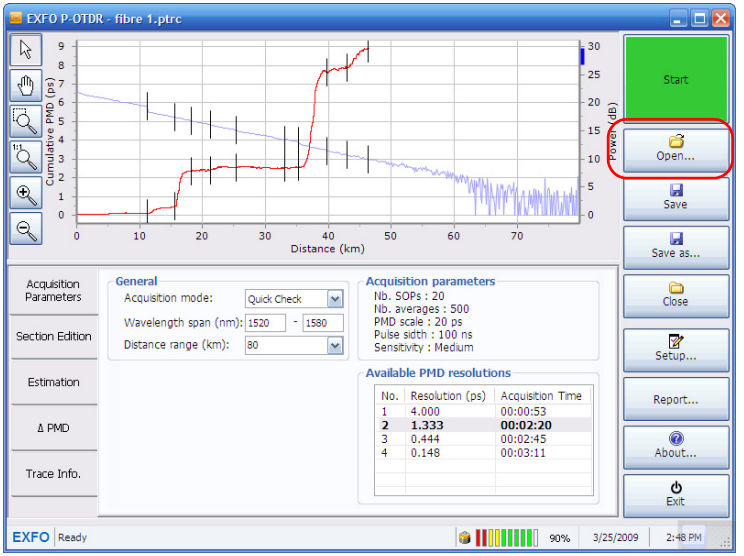
2. Select **P-OTDR**.
3. Press **Start Application**.

Opening an Existing File

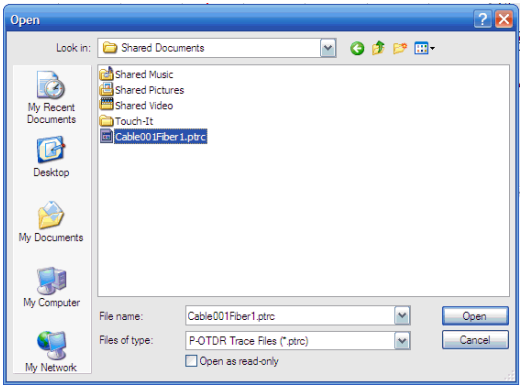
If you are working with the offline mode of the application, or want to open a file you have previously acquired, you can either open it and modify it as needed, or open it as a read-only file, to avoid any accidental modification.

To open an existing file:

1. From the main window, press **Open**.



2. Select the file you want to open. If you want the file to open in read-only mode, select the corresponding option.



3. Press **Open**.

Saving a File

Files can be saved either using the autonaming scheme or using a personalized name.

The autonaming scheme is only available if you have selected the option as explained in *Setting up Storage Options* on page 25 and if the file you are saving is a new acquisition (as opposed to an already existing file that you have opened).

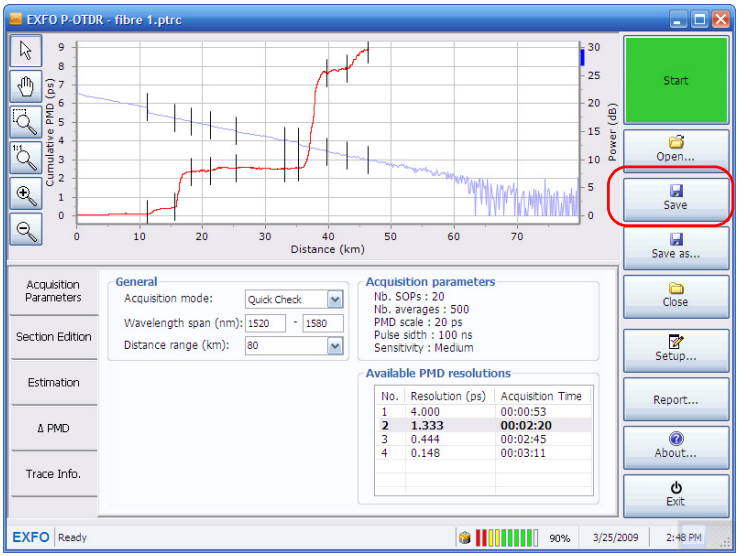
IMPORTANT

Since acquisition files can be extremely large, they are directly sent to the storage location and are not kept in memory to optimize the operation speed of the unit.

If the location you have selected for saving files is external to the unit (for example, a USB key or a drive linked through a network), you must leave the external storage device or link in place while you are working on your files. Otherwise, the unit cannot save the data and you will lose any change made since the time you removed the storage device or connection.

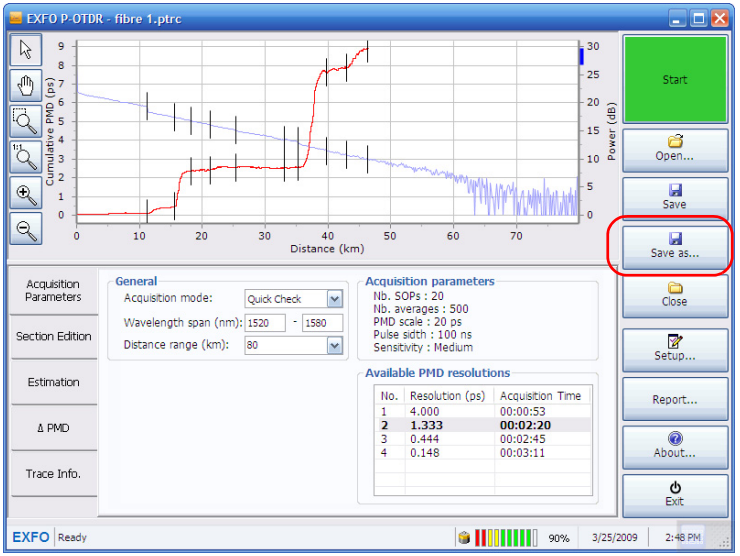
To save a file using the autonaming scheme:

From the main window, press **Save**.



To save a file using a personalized name:

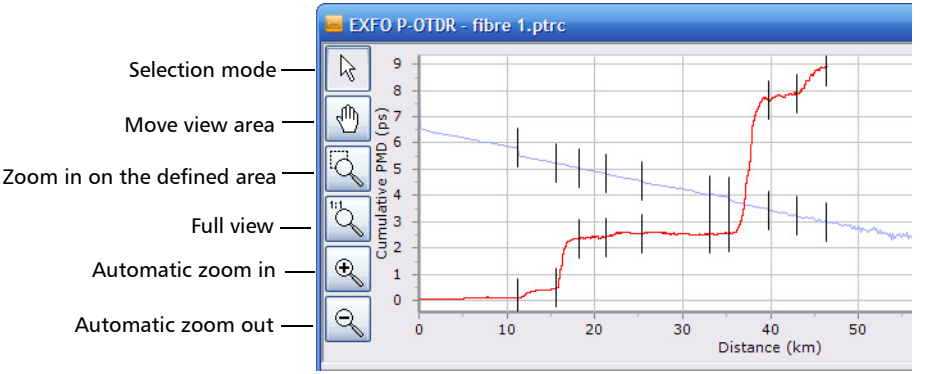
1. From the main window, press **Save As**.



2. Enter a name for the file, then press **Save**.

Using Zoom Controls

Use the zoom controls to change the scale of the trace display.



Note: *You cannot move the markers with the*  *button.*

To view specific portions of the graph:

- You can define which portion of the graph will be visible by selecting the  button and dragging the graph with the stylus or your finger.
- You can also zoom in on a specific area by selecting the  button and defining the zoom area with the stylus or your finger (a rectangle with dotted lines will appear to help you define the area). Once you release the stylus, the application automatically zooms in on the graph.
- You can zoom in or out on the center of the portion of the graph that is displayed by using, respectively, the  or the  button. The application automatically adjusts the zoom.

To revert to the complete graph view:

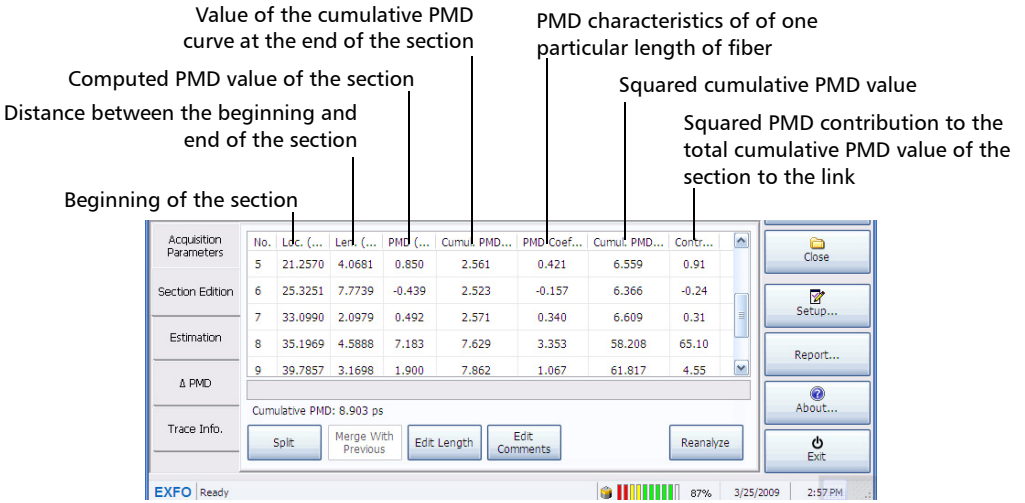
Press the  button.

Section Event Table

After the acquisition is complete, you can see that a trace and a curve appeared on-screen. They are the OTDR trace, and the cumulative PMD curve. The latter is computed from a set of data that is called an SOP (state of polarization). Several SOPs make one final cumulative PMD curve.

In order to interpret the measurements in the section table corresponding to the PMD curve and working with them, you must take into account that the PMD curve is square rooted. This means that the PMD value for each section is the square root difference of the PMD cumulative curve section's last value and the PMD cumulative curve section's first value.

Several indicators in the cumulative PMD table will help you with your measurements :



You will also notice the cumulative PMD value at the bottom of the table. This is particularly useful when you have many sections in your FUT and do not want to go up and down the table constantly between operations to see the cumulative value.

The *PMD section value* provides the PMD of a particular section over the link. The section's PMD value is the square root difference of the PMD cumulative curve section's last value and the PMD cumulative curve section's first value. The formula is:

$$PMDSection = \sqrt{CumulPMDSectionLastValue^2 - CumulPMDSectionFirstValue^2}$$

No.	Loc. (...	Len. (...	PMD (...	Cumul. PMD...	PMD Coef...	Cumul. PMD...	Contr...
1	0.0000	3.9839	0.369	0.369	0.185	0.136	0.11
2	3.9839	3.8716	9.929	9.936	5.046	98.716	77.75
3	7.8556	8.7488	5.299	11.260	1.791	126.795	22.14

The *contribution value* provides a way to evaluate the contribution of a specific section of the cumulative PMD of a link. Since PMD adds up to the square, the contribution is computed in squares. The percentage of contribution values are provided in square since it is mathematically not possible to provide a square rooted percentage. Values would simply not add up to 100 % and be harder to interpret.

Below, you can see an example of a fiber with two sections. The first section has a value of 5 ps and the second section, of 10 ps. This will result in a 11.2 ps of total cumulative PMD.

The percentage value of the first section is :

$$\text{Contribution} = \frac{5^2 \cdot 100\%}{10^2 + 5^2} = 20\%$$

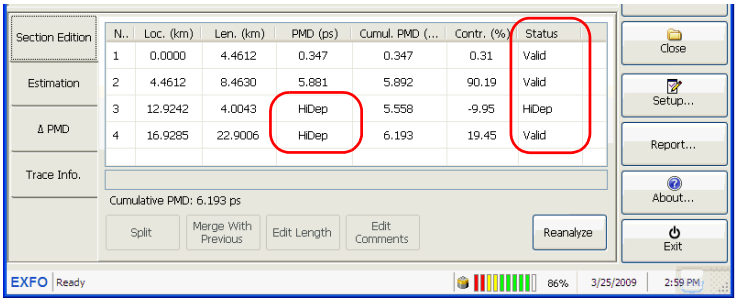
The percentage value of the second section is :

$$\text{Contribution} = \frac{10^2 \cdot 100\%}{10^2 + 5^2} = 80\%$$

In this example, removing the 10-ps section will make the cumulative PMD square of the link fall from 125 ps^2 to 25 ps^2. In a linear scale, it would fall from 11.18 ps to 5 ps. You must therefore always remember that the contribution is computed as square values.

Section Status

You can view the status of the section at all times in the table. If there is a problem with the PMD of a section, you can see a status in the table that will help you identify the quality of the measurement.



The statuses are explained in the table below:

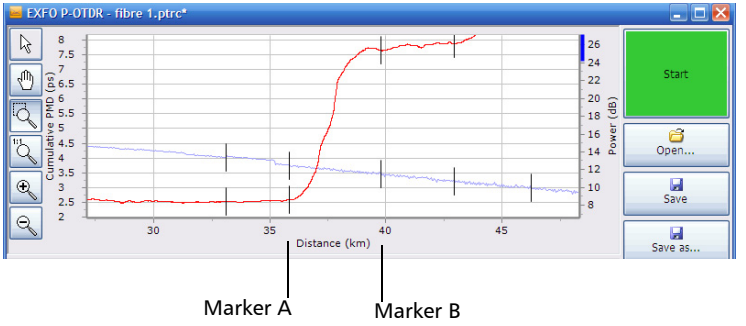
Status	In PMD column	In Status column	Suggestion
Valid	The PMD value is shown	The section is valid	
Under Range (UnRg)	The first or last point in the section has a PMD value that is too weak according to the residual PMD of the measurement.	A significant portion of the cumulated PMD curve for the section is to weak according to the measurement resolution.	Select a lower scale or a smaller PMD range in the acquisition parameters
Over Range (OvRg)	The first or last point in the section has a PMD value that is too high according to the selected PMD range.	A significant portion of the cumulated PMD curve for the section is too high according to the selected PMD scale.	Select a higher scale or broader PMD range in the acquisition parameters.
Low SNR (LoSNR)	The dynamics of the first or last point in the section are not sufficient to measure PMD correctly for the section.	The dynamics on the section is not sufficient to measure the cumulated PMD curve correctly.	Lessen the losses through the connectors, increase the number of averagings or increase the pulse size. For more information, see *Use an Optimized Number of Averagings* on page 127 and *Use an Appropriate OTDR Pulse Length* on page 128.

Status	In PMD column	In Status column	Suggestion
High Depolarization (HiDep)	The first or last point in the section shows a high intrinsic polarization level that causes the measurement to be imprecise.	The concerned section shows a strong level of intrinsic that causes the measurement to be imprecise.	The beating length, the local variations that have to be measured, is a lot shorter than the size of the pulse. Therefore the polarization fluctuation measured by the unit vanished through the pulses spatial averaging and is not picked up. To improve the situation, you can try to move the section cursors outside the region where the results are invalid, increase the spatial smoothing filter value or taking a measurement with a shorter pulse.

Status	In PMD column	In Status column	Suggestion
Unstable Link (Unst)	The first or last point in the section shows strong polarization unstability.	The section shows strong polarization unstability.	Unstable sections occur when on the link, the polarization moves at a speed faster than the acquisition time of a wavelength's step. This phenomenon can occur mainly when measuring aerial links when there are strong winds. Any section after an unstable section is unstable as well. To improve the situation, you can decrease significantly the number of averages.

Positioning Markers on the Display

Correctly positioning the cursors is a key element in having the appropriate results. The fundamental element is to set the first maker just before the beginning of the transition and the last marker just after the end of the transition.



Note: *When you position the markers for the PMD, you will see that they might not fit exactly with the automatically detected OTDR events on the trace. Working with the exact location of the OTDR event markers will take the network constraint into account, but adjusting the markers manually will provide you with optimized measurements for your link.*

If you use the spatial smoothing filter, you may have to adjust the markers, as the curve may change.

Editing Sections

Once your acquisition is complete the FTB-5600 built its own PMD section table based on the OTDR automatic detection event algorithm. Since most OTDR events do not coincide with PMD events, you may find that the table contains events that are irrelevant to your test. You may want to edit some sections of the link to improve your results.

Here is an example of a trace before and after irrelevant sections are cleaned out:

Trace before treatment

Trace after treatment

Splitting Fiber Sections

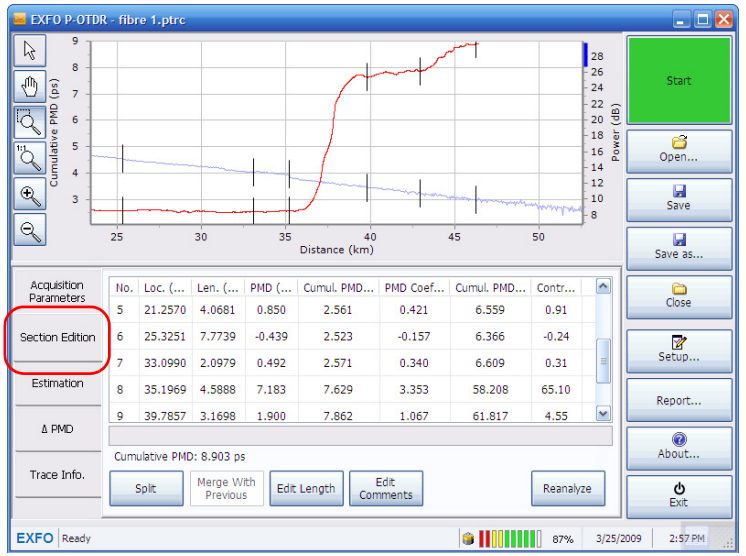
Splitting sections can allow you to define a new segment by separating an existing segment in two. This could help you pinpoint events that are more relevant to your analysis than those automatically detected.

IMPORTANT

Splitting a fiber section cannot be undone, unless you reanalyze the trace, as explained in *Viewing Trace Information* on page 85.

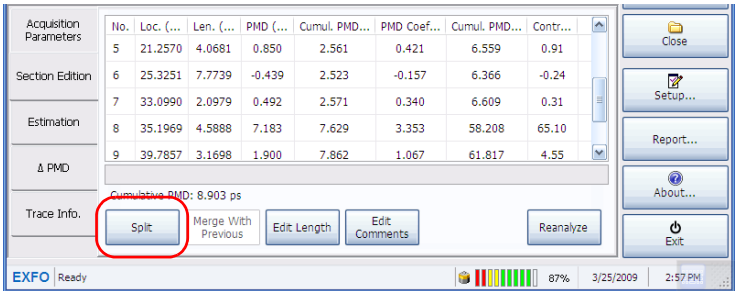
To split a fiber section:

1. From the main window, select the **Section Edition** tab.



2. Select the section you want to edit by pressing on it once.

3. Press **Split**.



4. Move the cursor using the arrow buttons to the desired location where you want to split the segment. You can also click-drag the cursor to the desired location.

   The new segment you are creating is indicated in red in the table. You will also see the two segments in gray on the graph.

Note: *If you had comments in the segment you are splitting, they will remain with the left-hand segment.*

5. Press on **Apply** to split the segment, or on **Cancel** to return to the **Section Edition** tab.

Merging Fiber Sections

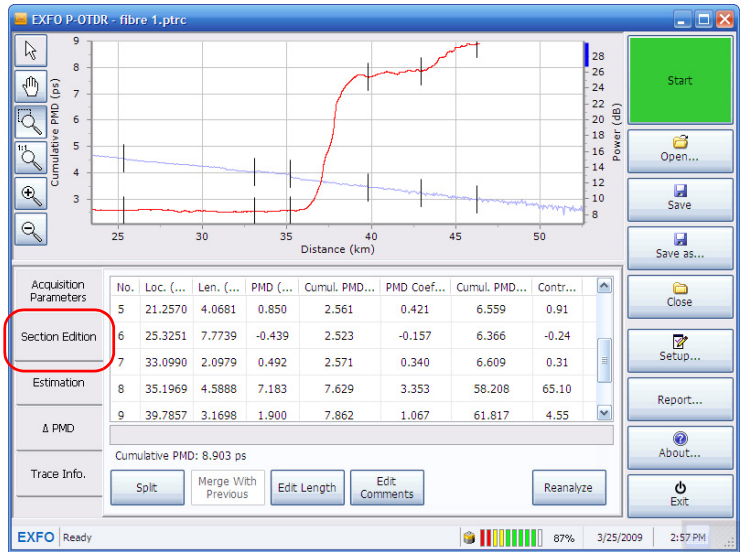
Merging fiber sections can be useful for removing irrelevant events.

IMPORTANT

Merging fiber sections cannot be undone, unless you reanalyze the trace, as explained in *Viewing Trace Information* on page 85.

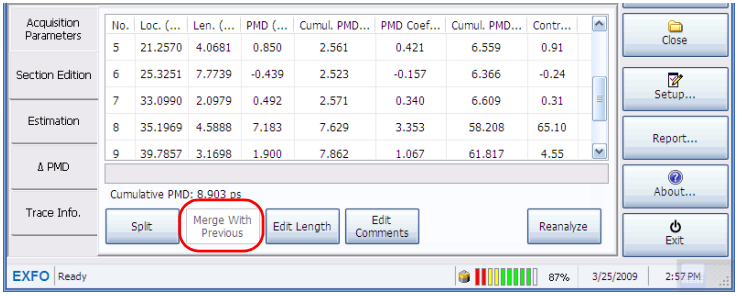
To merge a fiber section to another:

1. From the main window, select the **Section Edition** tab.

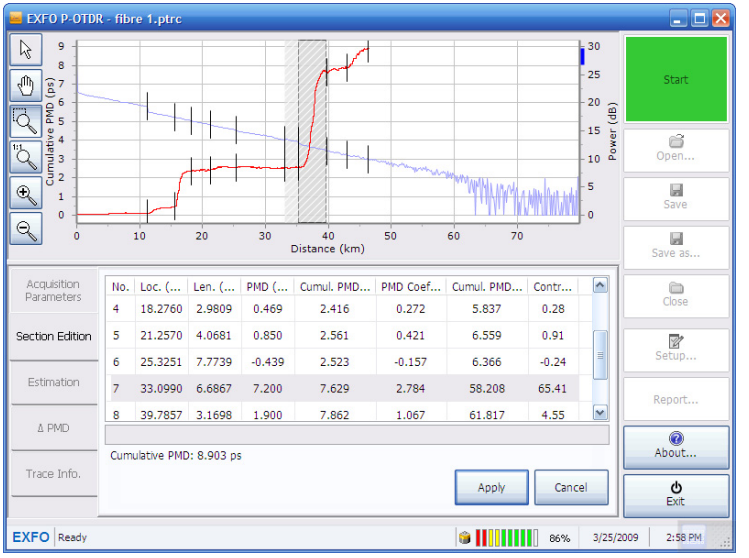


2. Select the section you want to merge by pressing on it once. The section is always merged with the one above it.

3. Press **Merge with Previous**.



The selected section is merged with the one above it, and you can see the results on-screen.



Note: *If there were comments in either section, they will be merged as well.*

4. Press **Apply** to accept the merge, or **Cancel** to return to the **Section Edition** tab.

Editing Section Length

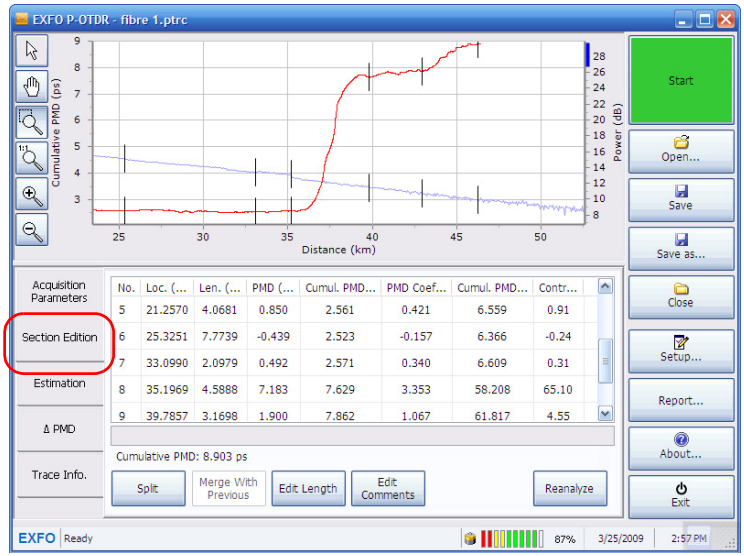
Editing the section length can allow you to include part of another section to improve the section table measurements.

IMPORTANT

Editing a fiber section length cannot be undone, unless you reanalyze the trace, as explained in *Viewing Trace Information* on page 85.

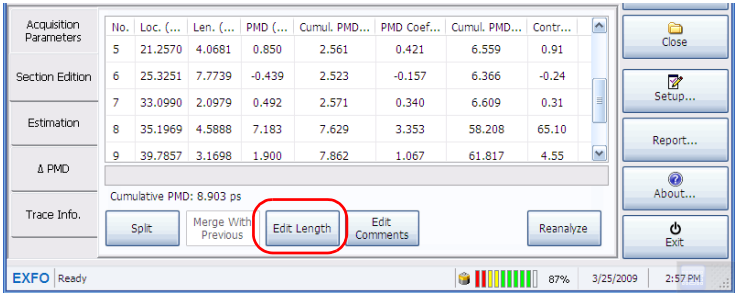
To edit a fiber section length:

1. From the main window, select the **Section Edition** tab.



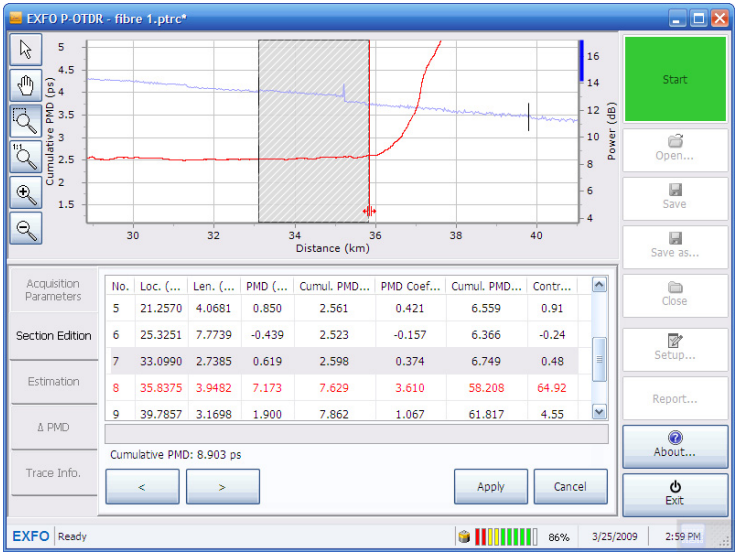
2. Select the section you want to edit by pressing on it once.

3. Press **Edit Length**.



4. Use the arrow buttons to move the right end of the segment to its new location. You can also click-drag the cursor to the desired position.

The other surrounding segments are updated accordingly.



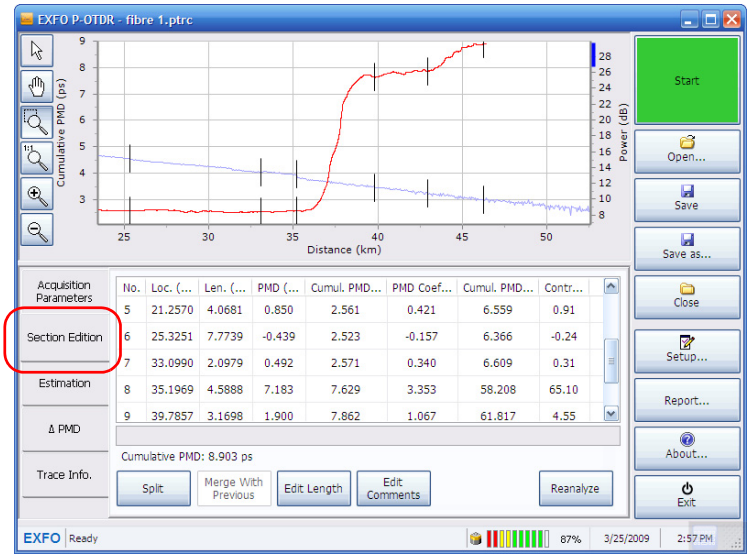
5. Press **Apply** to accept the new segment length, or **Cancel** to return to the **Section Edition** tab.

Adding Comments to Segments

You can add comments to each fiber section to include important information, or details on the events that could be helpful in later analyses.

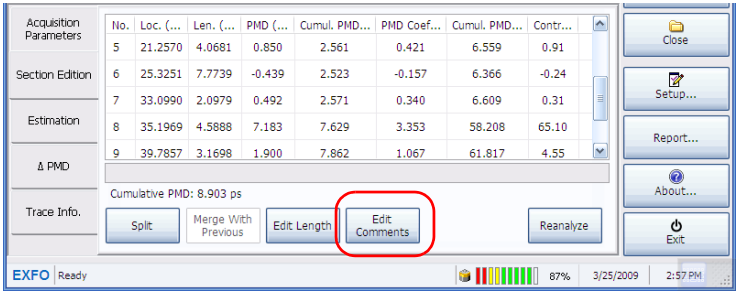
To add comments to a segment:

1. From the main window, select the **Section Edition** tab.

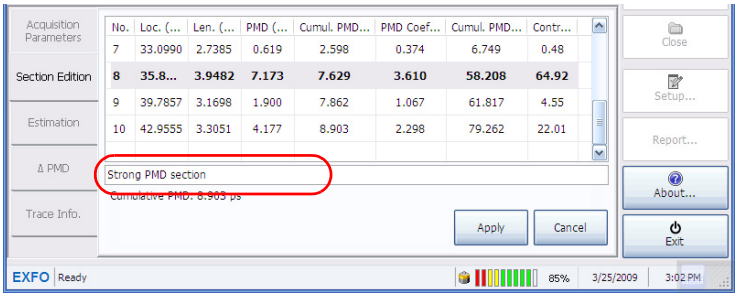


2. Select the segment for which you want to add a comment by pressing on it once.

3. Press **Edit Comments**.



4. Type in the comment you want to add, then press **Apply** to keep the comment, or **Cancel** to leave without adding a comment.



Using Markers to Measure PMD Differences (Delta PMD Tab)

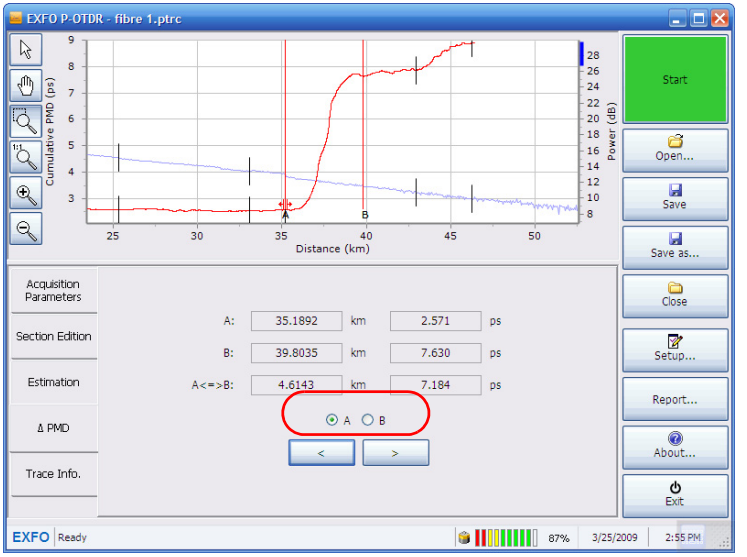
The Delta PMD tab is used to measure sections along the cumulative PMD curve. The measurement is performed with two cursors; cursor A indicates the beginning of the measurement and cursor B indicates the end. On screen, you will see the positions of the markers, as well as the PMD cumulative values. The application then computes and displays the square rooted difference between cumulative PMD at the position of the two markers.

The equation below illustrates how the difference is calculated.

$$\Delta PMD = \frac{CumulPMDCursorB^2 - CumulPMDCursorA^2}{\sqrt{\left|CumulPMDCursorB^2 - CumulPMDCursorA^2\right|}}$$

To move the markers:

1. Select the Δ **PMD** tab.
2. Select which cursor to move.



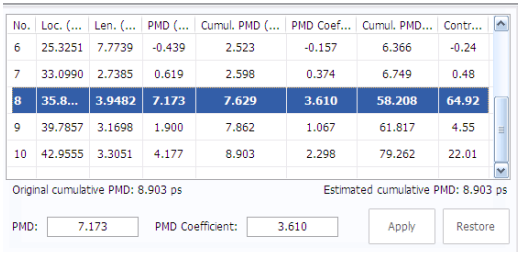
3. Use the arrow buttons to move the cursor. You can also click-drag the cursor to the desired position.

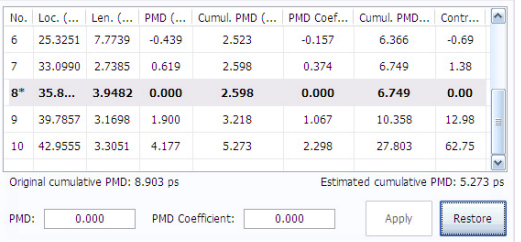
Estimating Results

You can manage the fiber sections as desired to obtain a better characterization. The FTB-5600 allows you to evaluate fiber section replacement scenarios in the link without actually replacing the section itself.

This is done by modifying one or some strong PMD sections of the link to analyze. By modifying the PMD value or the coefficient of the section in those links, you can see the simulated cumulative PMD value that will result from those changes.

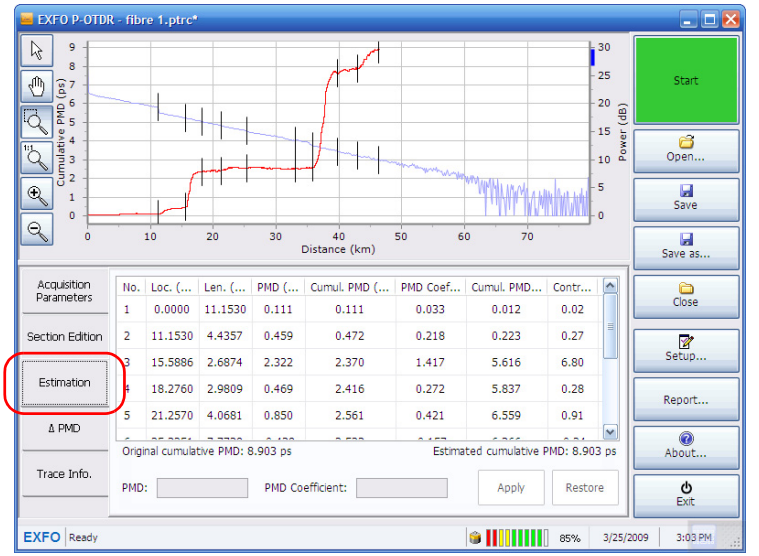
For example, you have made an acquisition with several sections. Let us verify what happens to the cumulative PMD of the link if we set PMD value of the eighth section to zero. The link cumulative PMD goes from 8.903 ps to 5.273 ps.





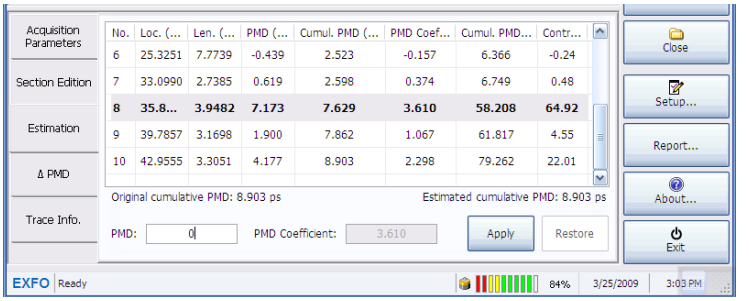
To work with the PMD estimation table:

1. From the main window, select the **Estimation** tab.



2. Select the row for which you want to change a value by pressing on it once.

3. Modify the PMD or PMD coefficient values, as desired.



4. Press **Apply** to se the changes to the link.

To revert to the original values for the selected row, press **Restore**.

Viewing Trace Information

Once your acquisition is complete, you can view the details about it in the **Trace Info.** tab. This information can be useful for future reference, or to perform other tests. For example, if you have performed a quick check on a link, you can now use the distance value calculated by the OTDR to put in a standard or advanced acquisition for the distance range value.

From the **Trace Info.** tab, you can also change the cable and job information, reanalyze a trace and change the spatial smoothing filter.

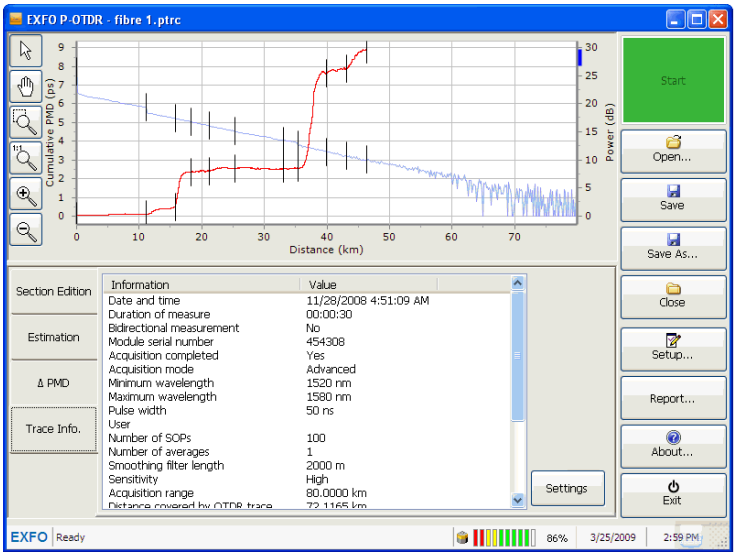
Note: *You can find more information about the spatial smoothing filter in* Setting up General Acquisition Parameters *on page 21 and* Use an Appropriate Spatial Smoothing Filter Value *on page 129.*

IMPORTANT

Reanalyzing a trace or changing the spatial smoothing filter will delete the current estimation table, all of the comments you may have added, as well as the modifications and estimations you have performed in the section table. If you want to retain this information for further use, you must save it before reanalyzing the trace.

To view the trace information:

From the main window, select the **Trace Info.** tab.

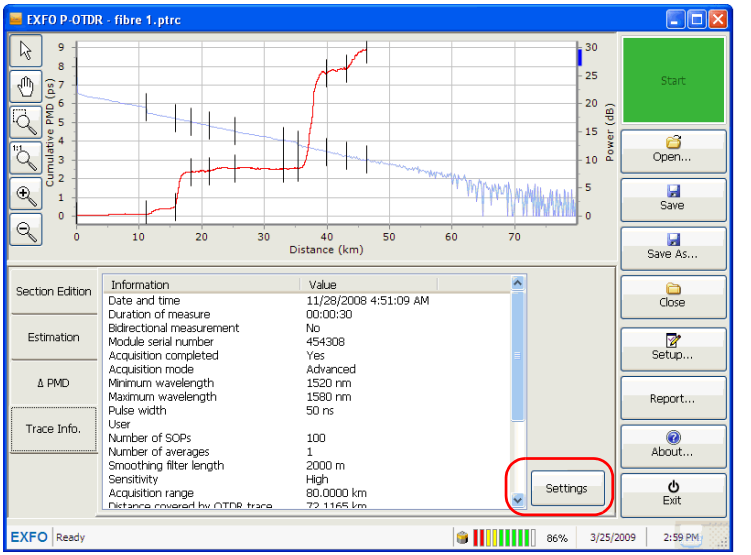


If you are viewing the trace information for a bidirectional trace file you have created with the Bidirectional File Creator utility, the information you see is that of the A -> B trace. However, some of the information is displayed differently :

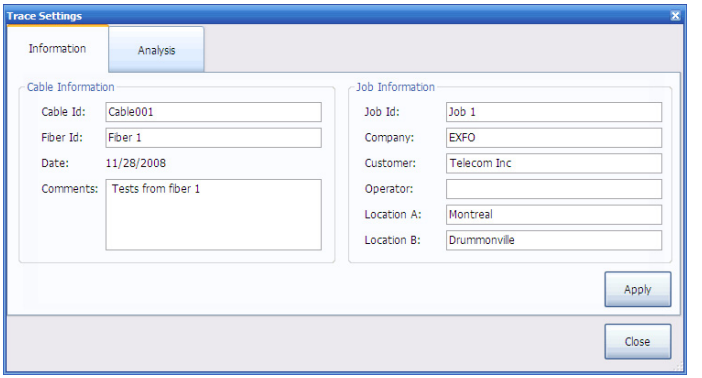
- The minimum wavelength is that of both measurements.
- The maximum wavelength is that of both measurements.
- The maximum number of SOPs is that of both measurements.
- The number of averagings is the maximum value of both measurements.
- The acquisition range is the maximum value of both measurements.
- The PMD scale is the maximum value of both measurements.
- The PMD resolution is the minimum value of both measurements.
- The distance covered by the OTDR trace is the length of the link.
- The distance covered by the PMD trace is the length analyzed in bidirectional mode.

To change the cable and job information:

1. From the main window, select the **Trace Info.** tab.
2. Press **Settings**.



3. Select the **Information** tab.



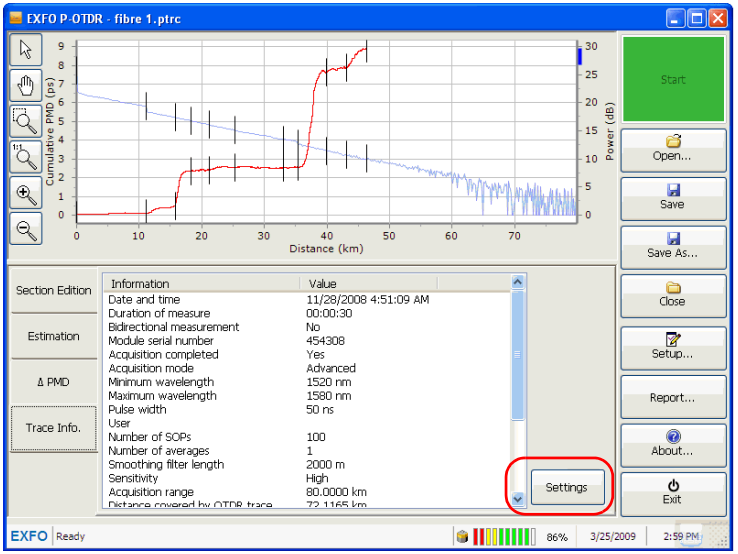
4. Enter information as desired. If you have already entered some information in the **Cable Information** window as explained in *Setting up Cable Information* on page 31, it will already be in the corresponding boxes.

5. Press **Apply** to use the new information, then **Close** to exit the window.

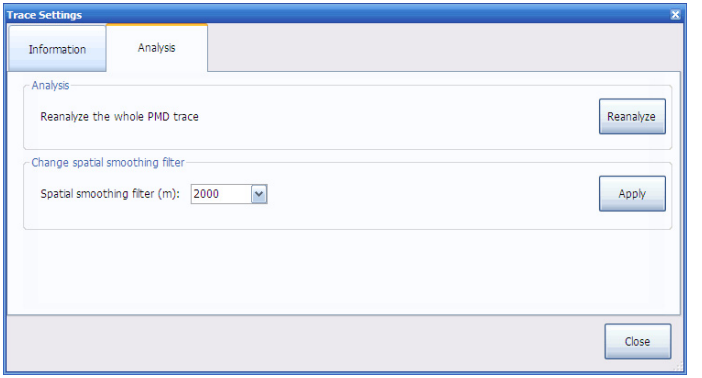
To perform a new analysis on a trace:

1. From the main window, select the **Trace Info.** tab.

2. Press **Settings**.



3. Select the **Analysis** tab.

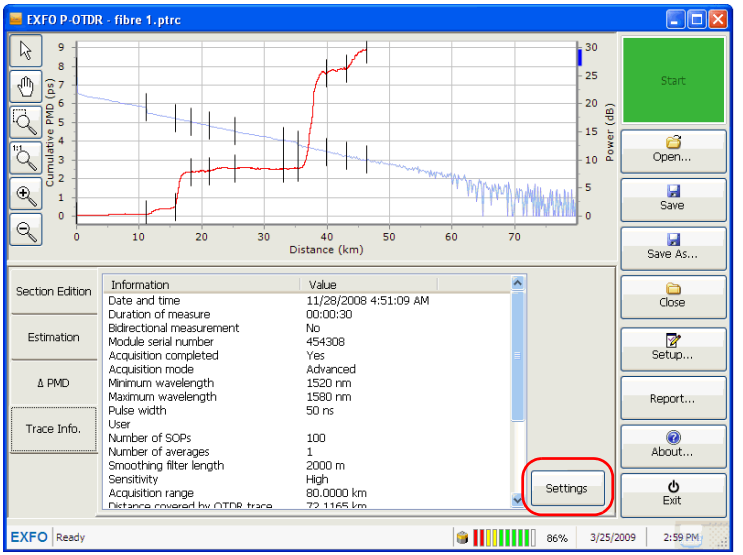


4. Press **Reanalyze**.

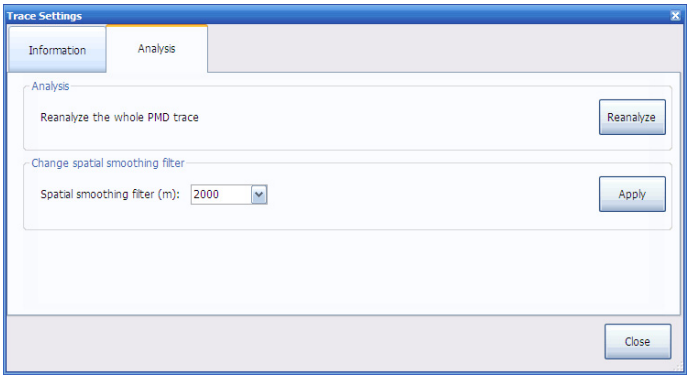
5. Press **Close** to return to the application.

To change the spatial smoothing filter:

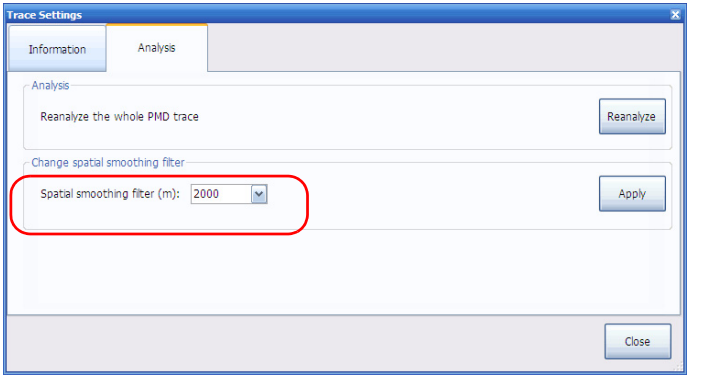
1. From the main window, select the **Trace Info.** tab.
2. Press **Settings**.



3. Select the **Analysis** tab.



4. Change the filter value to the desired value in the list.



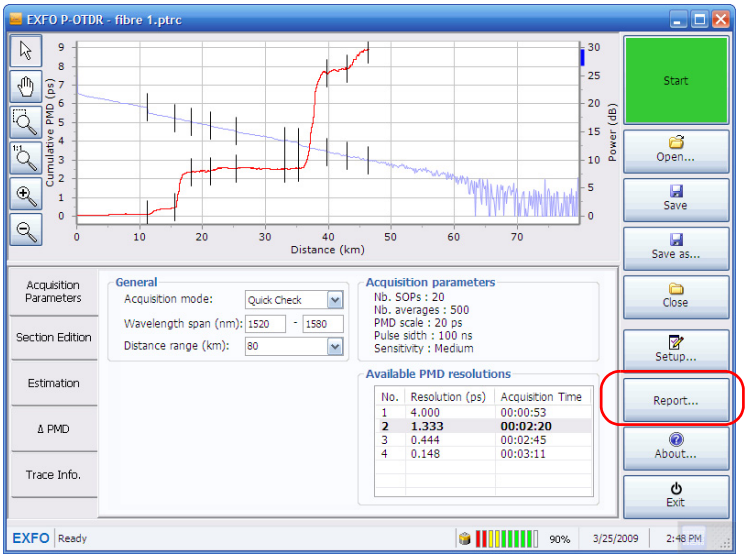
5. Press **Apply** to use this new value, then **Close** to exit the window.

Generating Reports

Once your trace is cleaned up and that your measurements are optimized, you can generate a report. This report can then be printed, or saved for future consultation.

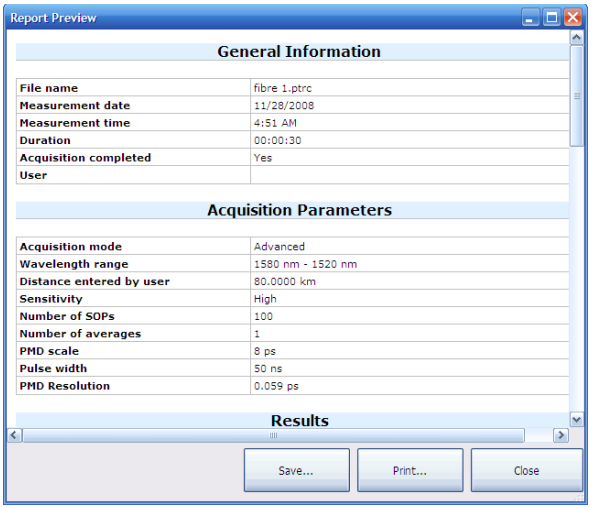
To generate a report:

1. From the main window, press **Report**.



2. In the **Report Preview** window, select what you want to do:

- Press **Save** to store the file. A standard **Save As** window opens to let you select a name and location.
- Press **Print** to send the document to your printer. A standard **Print** window opens to let you select the printing options.
- Press **Close** to return to the main window.



6 Maintenance

To help ensure long, trouble-free operation:

- Always inspect fiber-optic connectors before using them and clean them if necessary.
- Keep the unit free of dust.
- Clean the unit casing and front panel with a cloth slightly dampened with water.
- Store unit at room temperature in a clean and dry area. Keep the unit out of direct sunlight.
- Avoid high humidity or significant temperature fluctuations.
- Avoid unnecessary shocks and vibrations.
- If any liquids are spilled on or into the unit, turn off the power immediately, disconnect from any external power source, remove the batteries and let the unit dry completely.

WARNING

Use of controls, adjustments, and procedures for operation and maintenance other than those specified herein may result in hazardous radiation exposure.

Cleaning EUI Connectors

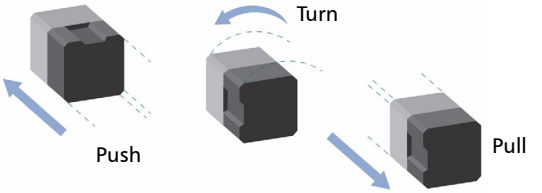
Regular cleaning of EUI connectors will help maintain optimum performance. There is no need to disassemble the unit.

IMPORTANT

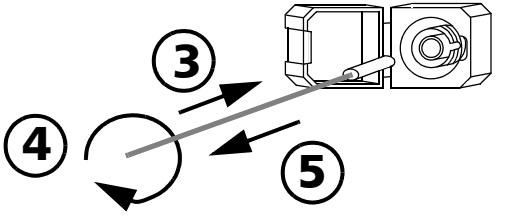
If any damage occurs to internal connectors, the module casing will have to be opened and a new calibration will be required.

To clean EUI connectors:

1. Remove the EUI from the instrument to expose the connector baseplate and ferrule.



2. Moisten a 2.5 mm cleaning tip with *one drop* of isopropyl alcohol (alcohol may leave traces if used abundantly).
3. Slowly insert the cleaning tip into the EUI adapter until it comes out on the other side (a slow clockwise rotating movement may help).



4. Gently turn the cleaning tip one full turn, then continue to turn as you withdraw it.

5. Repeat steps 3 to 4 with a dry cleaning tip.

Note: *Make sure you don't touch the soft end of the cleaning tip.*

6. Clean the ferrule in the connector port as follows:

6a. Deposit *one drop* of isopropyl alcohol on a lint-free wiping cloth.

IMPORTANT

Isopropyl alcohol may leave residues if used abundantly or left to evaporate (about 10 seconds).

Avoid contact between the tip of the bottle and the wiping cloth, and dry the surface quickly.

6b. Gently wipe the connector and ferrule.

6c. With a dry lint-free wiping cloth, gently wipe the same surfaces to ensure that the connector and ferrule are perfectly dry.

6d. Verify connector surface with a portable fiber-optic microscope(for example, EXFO's FOMS) or fiber inspection probe(for example, EXFO's FIP).

WARNING

Verifying the surface of the connector WHILE THE UNIT IS ACTIVE WILL result in permanent eye damage.

7. Put the EUI back onto the instrument (push and turn clockwise).

8. Throw out cleaning tips and wiping cloths after one use.

Recalibrating the Unit

Manufacturing and service center calibrations are based on the ISO/IEC 17025 Standard, which states that calibration documents must not contain a recommended calibration interval, unless this has been previously agreed upon with the customer.

Validity of specifications depends on operating conditions. For example, the calibration validity period can be longer or shorter depending on the intensity of use, environmental conditions and unit maintenance. You should determine the adequate calibration interval for your unit according to your accuracy requirements.

Under normal use, EXFO recommends calibrating your unit every year.

Recycling and Disposal (Applies to European Union Only)

Recycle or dispose of your product (including electric and electronic accessories) properly, in accordance with local regulations. Do not dispose of it in ordinary garbage receptacles.

This equipment was sold after August 13, 2005 (as identified by the black rectangle).

- Unless otherwise noted in a separate agreement between EXFO and a customer, distributor, or commercial partner, EXFO will cover costs related to the collection, treatment, recovery, and disposal of end-of-lifecycle waste generated by electronic equipment introduced after August 13, 2005 to an European Union member state with legislation regarding Directive 2002/96/EC.
- Except for reasons of safety or environmental benefit, equipment manufactured by EXFO, under its brand name, is generally designed to facilitate dismantling and reclamation.

For complete recycling/disposal procedures and contact information, visit the EXFO Web site at www.exfo.com/recycle.

7 Troubleshooting

Should you have problems with your unit, you can try the following:

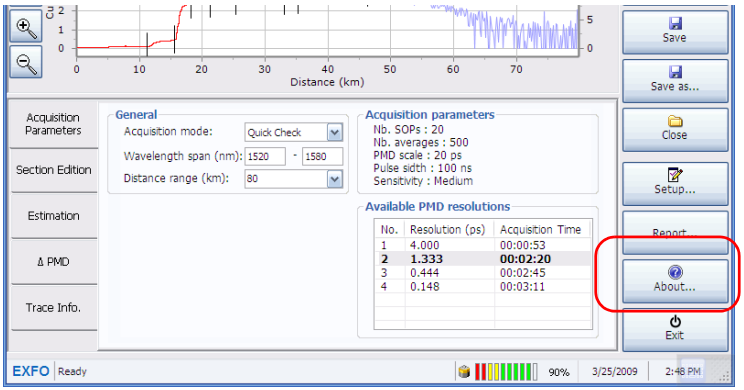
Obtaining Online Help

An online version of the FTB-5600 Distributed PMD Analyzer user guide is available at all times from the application.

Note: *You will also find a printable PDF version on your installation CD.*

To access online help:

In the button bar, click **About** then click **User Guide**.

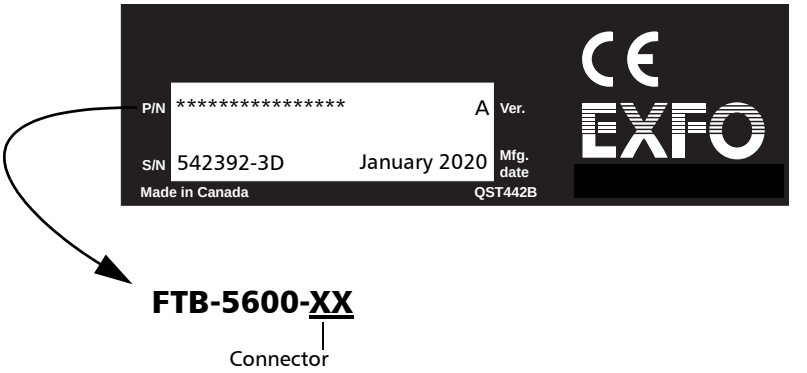


Contacting the Technical Support Group

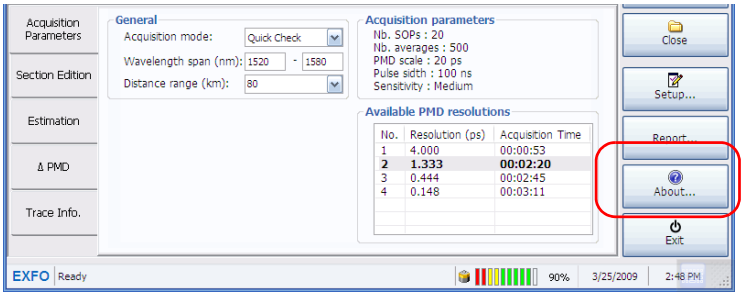
To obtain after-sales service or technical support for this product, contact EXFO at one of the following numbers. The Technical Support Group is available to take your calls from Monday to Friday, 8:00 a.m. to 7:00 p.m. (Eastern Time in North America).

For detailed information about technical support, visit the EXFO Web site at www.exfo.com.

To accelerate the process, please have information such as the name and the serial number (see the product identification label—an example is shown below), as well as a description of your problem, close at hand.



You may also be requested to provide software and module version numbers. This information, as well as technical support contact information, can be found in the **About** function tab.



Transportation

Maintain a temperature range within specifications when transporting the unit. Transportation damage can occur from improper handling. The following steps are recommended to minimize the possibility of damage:

- Pack the unit in its original packing material when shipping.
- Avoid high humidity or large temperature fluctuations.
- Keep the unit out of direct sunlight.
- Avoid unnecessary shocks and vibrations.

8 Warranty

General Information

EXFO Electro-Optical Engineering Inc. (EXFO) warrants this equipment against defects in material and workmanship for a period of one year from the date of original shipment. EXFO also warrants that this equipment will meet applicable specifications under normal use.

During the warranty period, EXFO will, at its discretion, repair, replace, or issue credit for any defective product, as well as verify and adjust the product free of charge should the equipment need to be repaired or if the original calibration is erroneous. If the equipment is sent back for verification of calibration during the warranty period and found to meet all published specifications, EXFO will charge standard calibration fees.

IMPORTANT

The warranty can become null and void if:

- **unit has been tampered with, repaired, or worked upon by unauthorized individuals or non-EXFO personnel.**
- **warranty sticker has been removed.**
- **case screws, other than those specified in this guide, have been removed.**
- **case has been opened, other than as explained in this guide.**
- **unit serial number has been altered, erased, or removed.**
- **unit has been misused, neglected, or damaged by accident.**

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. IN NO EVENT SHALL EXFO BE LIABLE FOR SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Liability

EXFO shall not be liable for damages resulting from the use of the product, nor shall be responsible for any failure in the performance of other items to which the product is connected or the operation of any system of which the product may be a part.

EXFO shall not be liable for damages resulting from improper usage or unauthorized modification of the product, its accompanying accessories and software.

Exclusions

EXFO reserves the right to make changes in the design or construction of any of its products at any time without incurring obligation to make any changes whatsoever on units purchased. Accessories, including but not limited to fuses, pilot lamps, batteries and universal interfaces (EUI) used with EXFO products are not covered by this warranty.

This warranty excludes failure resulting from: improper use or installation, normal wear and tear, accident, abuse, neglect, fire, water, lightning or other acts of nature, causes external to the product or other factors beyond the control of EXFO.

IMPORTANT

EXFO will charge a fee for replacing optical connectors that were damaged due to misuse or bad cleaning.

Certification

EXFO certifies that this equipment met its published specifications at the time of shipment from the factory.

Service and Repairs

EXFO commits to providing product service and repair for five years following the date of purchase.

To send any equipment for service or repair:

1. Call one of EXFO's authorized service centers (see *EXFO Service Centers Worldwide* on page 109). Support personnel will determine if the equipment requires service, repair, or calibration.
2. If equipment must be returned to EXFO or an authorized service center, support personnel will issue a Return Merchandise Authorization (RMA) number and provide an address for return.
3. If possible, back up your data before sending the unit for repair.
4. Pack the equipment in its original shipping material. Be sure to include a statement or report fully detailing the defect and the conditions under which it was observed.
5. Return the equipment, prepaid, to the address given to you by support personnel. Be sure to write the RMA number on the shipping slip. *EXFO will refuse and return any package that does not bear number.*

Note: *A test setup fee will apply to any returned unit that, after test, is found to meet the applicable specifications.*

After repair, the equipment will be returned with a repair report. If the equipment is not under warranty, you will be invoiced for the cost appearing on this report. EXFO will pay return-to-customer shipping costs for equipment under warranty. Shipping insurance is at your expense.

Routine recalibration is not included in any of the warranty plans. Since calibrations/verifications are not covered by the basic or extended warranties, you may elect to purchase FlexCare Calibration/Verification Packages for a definite period of time. Contact an authorized service center (see *EXFO Service Centers Worldwide* on page 109).

EXFO Service Centers Worldwide

If your product requires servicing, contact your nearest authorized service center.

EXFO Headquarters Service Center
400 Godin Avenue
Quebec (Quebec) G1M 2K2
CANADA

1 866 683-0155 (USA and Canada)
Tel.: 1 418 683-5498
Fax: 1 418 683-9224
quebec.service@exfo.com

EXFO Europe Service Center
Omega Enterprise Park, Electron Way
Chandlers Ford, Hampshire S053 4SE
ENGLAND

Tel.: +44 2380 246810
Fax: +44 2380 246801
europe.service@exfo.com

EXFO China Service Center/ Beijing OSIC
Beijing New Century Hotel
Office Tower, Room 1754-1755
No. 6 Southern Capital Gym Road
Beijing 100044
P. R. CHINA

Tel.: +86 (10) 6849 2738
Fax: +86 (10) 6849 2662
beijing.service@exfo.com

A Technical Specifications

IMPORTANT

The following technical specifications can change without notice. The information presented in this section is provided as a reference only. To obtain this product's most recent technical specifications, visit the EXFO Web site at *www.exfo.com*.

SPECIFICATIONS [a]

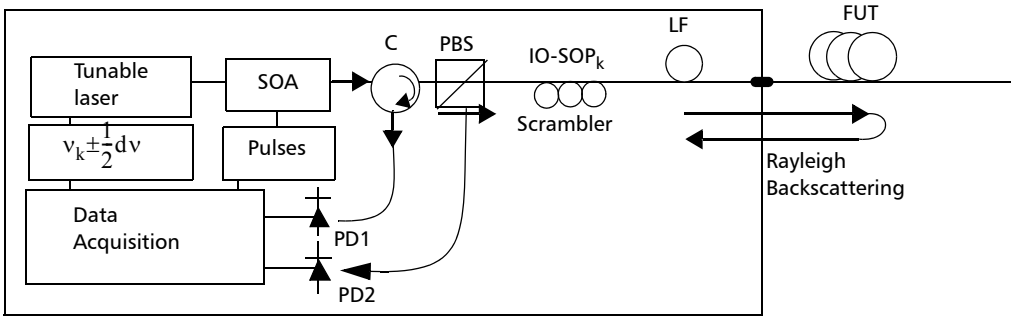
Wavelength range (nm)	1520 to 1580
Maximum cumulative PMD (ps)	≥20
Minimum measurable cumulative PMD (ps)	0.1 [b]
Cumulative PMD uncertainty (ps)	± (0.1 + 5 % x PMD) [c]
PMD dynamic range (dB)	15 [d]
Distance uncertainty (OTDR) (m)	±10 [e]

GENERAL SPECIFICATIONS

Temperature		
Operating	0 °C to 40 °C	(32 °F to 104 °F)
Storage	–40 °C to 70 °C	(–40 °F to 158 °F)
Relative humidity	0 % to 93 % non-condensing [f]	
Size (H x W x D)	96 mm x 75 mm x 281 mm	(3 3/4 in x 3 in x 11 in)
Weight	2 kg	(4.4 lb)

B Distributed Cumulative PMD Measurement Theory

The FTB-5600 is a Distributed PMD Analyzer that uses a random-scrambling tunable-polarization-sensitive OTDR (RS-POTDR) to measure the cumulative PMD as a function of the distance along a single-mode optical fiber. In this way, bad high-PMD fiber sections can be identified and quantified. The basic FTB-5600 design is illustrated schematically in the figure below.



The output from a tunable laser is modulated and amplified by a semiconductor optical amplifier (SOA) to produce standard OTDR light pulses having a narrow spectral width of ~4 GHz (FWHM). The OTDR pulses are routed by a circulator (C) and a polarization beam splitter (PBS), serving as a polarization analyzer, before passing through an input-and-output state-of-polarization (I/O-SOP) scrambler.

The I/O-SOP randomly selects both the SOP of light, which is input into the FUT and the SOP of the Rayleigh backscattered light. The Rayleigh backscattered light from the FUT travels back through the I/O-SOP scrambler, is split into two orthogonal-polarization portions by the PBS, and these portions are then measured by photodetectors 1 and 2 (that is, PD1 and PD2). This detection is time-gated, as with any conventional OTDR, allowing the P-OTDR raw data to be acquired.

The typical OTDR pulse length used for the RS-POTDR is of 100 ns or 50 ns. A low-PMD lead fiber (LF) is used for probing coherence noise arising from the moderately high coherence of the laser source, allowing it to be largely eliminated in the subsequent data processing.

The P-OTDR traces $P_j(z_n)$ as a function of distance z are acquired for many different random and independent combinations of optical central frequency ν_k and I/O-SOP. The transmission $T_j(z_n)$ of the analyzed light is computed from the traces measured from two photodetectors, $P_{xj}(z_n)$ and $P_{yj}(z_n)$, point by point as,

$$T_j(z_n) = \frac{P_{xj}(z_n)}{P_{xj}(z_n) + P_{yj}(z_n)}$$

In the FTB-5600, P-OTDR traces are acquired in pairs for two closely-spaced optical frequencies, $\nu_k \pm ¾\delta\nu$, with the same I/O-SOP. The central frequency ν_k of each pair is generally different from that of any other pair. Although the I/O-SOP corresponding to traces within each pair must be the same, they are generally different from one pair to another.

For each pair of P-OTDR traces, a corresponding local transmission difference, $\Delta T_k(z_n)$, can be calculated at each distance point z_n. Typically, the data is acquired from a large number K (≥ 100) of pairs leading to K transmission differences for a random set of independent K combinations of central frequency and I/O-SOP, that is, ν_k, I/O-SOP$_k$, where k = 1, 2 … K. Closely-spaced means $PMD_m \cdot \delta\nu < 0.1$ to 0.15, where PMD_m is the largest value to be measured and $\delta\nu$ is an optical-frequency difference for all pairs.

The use of an optimized maximum optical-frequency difference leads to the best SNR; for example, to measure a maximum PMD value of 10 ps, an optimized $\delta\nu$ is ~12.5 GHz. It should be noted that the PMD measured with this instrument is the rms average of the Differential Group Delay (DGD) over a wide wavelength range.

An OTDR-based measurement is necessarily a “round-trip” measurement from any given point z_n along the fiber. Of course, what is of interest to most users is the cumulative PMD in the forward direction only. The

cumulative PMD from 0 to z_n is determined by multiplying the roundtrip-PMD by the statistical, averaging roundtrip factor $\alpha_{rt}2 = 3/8$, where the roundtrip-PMD at point z_n is deduced from the mean-square (ms) value of the K random transmission differences divided by a relative variance of the traces. More precisely, in practice, each of the two traces in each pair is acquired twice consecutively in time, thus producing a repeated pair having a difference of $\Delta T'_k(z_n)$, which may differ somewhat from $\Delta T_k(z_n)$. In this way, any change in the local difference between repeated pairs would be caused only by uncorrected noise. When averaged over all the different independent pairs, an ms-difference can be computed as the second-order joint moment of the repeated differences, thereby eliminating this noise offset.

$$\Delta T_{ms} z_n = \frac{1}{\sigma_r^2(z_n)} \langle \Delta T_k(z_n) \Delta T'_k(z_n) \rangle_K$$

In order to attain a maximum dynamic range and to minimize the coherence noise in the backscattered lights, the FTB-5600 generally uses long pulses (for example, 100 ns or 50 ns). However, depending upon the local birefringence at any given point zn, the backscattered light corresponding to this point may be partially depolarized, thereby “washing out” the transmission differences. The division of the joint moment by the relative variance $\sigma_r^2(z_n) = (\langle T_j(z_n) T'_j(z_n) \rangle_J - \langle T_j(z_n) \rangle_J^2) \cdot \sigma_T^{-2}$ in the equation above allows this effect to be effectively compensated (here $\sigma_T^2 = 4/45$ is a theoretical variance of the transmission for an infinitesimally short pulse). Note that the $\sigma_r^2(z_n)$ is also computed as a joint moment of repeated traces to avoid noise offset and averaged over the traces obtained for different wavelengths and uniformly distributed I/O-SOPs.

For very small values of PMD·δν, the ms-difference $\Delta T_{ms}(z_n)$ is proportional to $(\mathrm{PMD}\cdot\delta\nu)^2$. Hence, there the measured transmission differences may be very small, leading to a very poor dynamic range, since the differences may be of the same magnitude as the coherence noise. In order to use the *largest* possible optical-frequency difference δν, the large-step formula below is used to compute the cumulative PMD:

$$\Delta T_{ms}(z_n) = \Delta T_o^2\left[1 - \exp\left(-\left(\frac{2\pi \mathrm{PMD}(z_n)\delta\nu}{\alpha_{rt}\alpha_{dT}\Delta T_o}\right)^2\right)\right]$$

where $\Delta T_o^2 = 8/45$ is a "saturated" value of the ms-difference when PMD·δν → ∞ and $\alpha_{dT} = 15$ is a proportional constant when δν → 0.

When the PMD is obtained from a single measurement at a given time, the cumulative PMD curve, $PMD(z_n)$, will exhibit fluctuations as a function of distance z, even if the cumulative PMD is constant. Therefore, it can be advantageous to average over some length Δz, for example 0.5 km to 4 km, to obtain a clear picture of the cumulative PMD curve. Moreover, the use of a larger number of random and independent combinations of frequency and I/O-SOP, for example K = 200 to 500, permits a corresponding reduction in the measurement uncertainty.

C Acquisition Data

The purpose of the acquisition data is to build a PMD cumulative curve. This curve is build from OTDR traces taken at multiple frequencies or wavelengths, each being launched with a particular polarisation state.

The cumulative PMD from 0 to z_n is deduced from the mean-square (ms) value of the K random transmission differences divided by a relative variance of the traces. The mean-square (ms) value is computed according to the following equation:

$$\Delta T_{ms}(z_n) = \frac{1}{\sigma_r^2(z_n)} \langle \Delta T_k(z_n) \Delta T'_k(z_n) \rangle_k$$

More precisely, in practice each of the two traces in each pair is acquired twice consecutively in time, thus producing a repeated pair having a difference $\Delta T'_k(z_n)$ which may differ somewhat from $\Delta T_k(z_n)$.

The P-OTDR traces $P_j(z_n)$ as a function of distance z are acquired for many different random and independent combinations of optical central frequency ν_k and I/O-SOP. The transmission $T_j(z_n)$ of the analyzed light is computed from the OTDR traces measured from two photodetectors, $P_{xj}(z_n)$ and $P_{yj}(z_n)$, point by point as,

$$T_j = \frac{P_{xj}}{P_{xj} + P_{yj}}$$

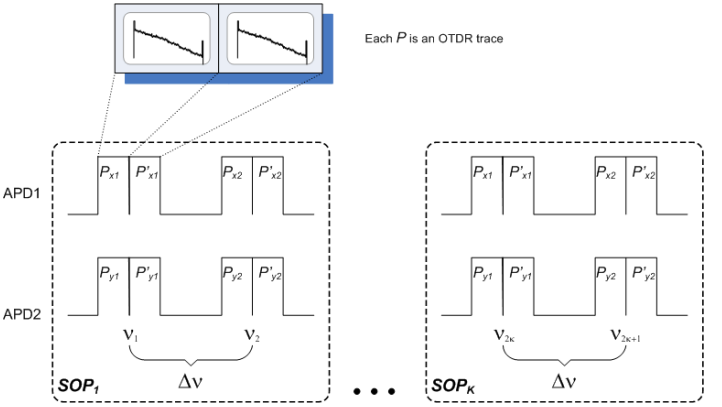
$$T_j' = \frac{P_{xj}'}{P_{xj}' + P_{yj}'},$$

For the sake of simplicity, the (z_n) notation of distance has been dropped. The P_x traces comes from the first branch of the PBS and the P_y traces, comes from the other branch of the PBS.

In the FTB-5600, P-OTDR traces are acquired in pairs for two closely-spaced optical frequencies, $\nu_k \pm \frac{1}{2}\delta\nu$ with the same I/O-SOP. The central frequency ν_k of each pair is in general different than that of any other pair. Although the I/O-SOP corresponding to traces within each pair must be the same, they are generally different from one pair to another.

This overall process is shown in the figure below:

Note: *Each P instance represents an OTDR trace.*



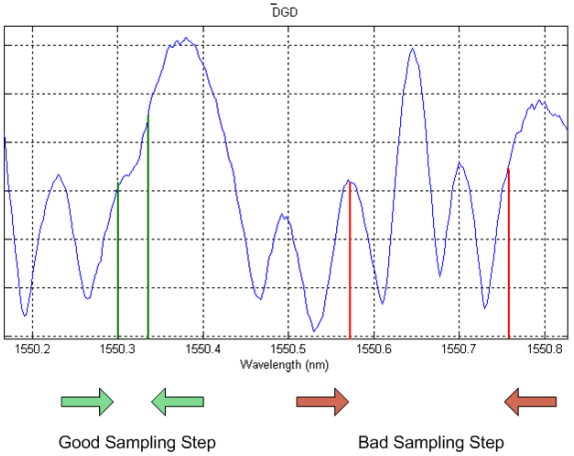
In order to settle up an acquisition, you will note that since the acquisition consist of OTDR traces, you must set the OTDR trace parameters such as the range, pulse and number of averages. For the PMD part, you must set the number of SOPs, the frequency range, and the frequency steps (through the PMD scale and the residual PMD).

In the example above, each SOP is build from eight OTDR traces. If you take another example of an acquisition of of 100 SOPs and 3 steps, plus the intermediate data, would result in 2400 OTDR traces
(3 steps x 8 traces x 100 SOPs).

To measure the PMD, you need to take the frequency step according to the PMD value. The reason is that the frequency sampling step must be less than one half the period of DGD fluctuation to obtain the best measurement.

A lower sampling rate will not allow a correct measurement, because of the violation of the Nyquist sampling criteria. A sampling rate that is too high will result in a measurement that is too noisy.

The figure below gives an example of a correct step and of a step which is too large to measure the variation of the signal properly.



For example, if a PMD curve can span from 0 to 20 ps, one sampling step is not enough to compute the curve over the entire PMD span. This is why many scales are necessary to build the PMD curve.

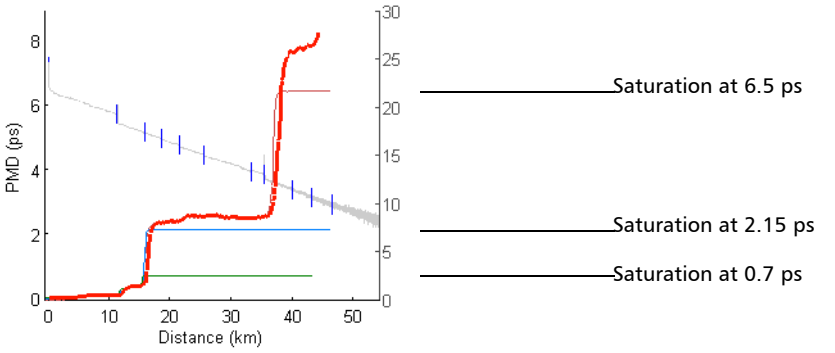
One frequency step can measure from 20 % and saturates at 240 % of its value. As an example, the 20 ps step can measure from 5 to 48 ps.

The FTB-5600 takes care of this issue: it automatically computes all of the sampling steps required between the span provided. Only the value at the end of the link (the PMD scale), and the minimum value desired (the residual PMD) need to be set.

Note: *The PMD sampling steps overlap by 3.*

In the example below, the chosen scale is 8 ps and the residual PMD of 60 fs. We can see each scales with their saturation level and how they are used to compute the overall PMD curve.

Scale (ps)	Step (GHz)	Residual PMD (ps)	Saturation (ps)
8	12.5	1.6	19.4
2.67	37.5	0.533	6.5
0.889	112	0.178	2.15
0.296	337	**0.06**	0.7



D Optimizing Measurements

Firstly the FTB-5600 measures the cumulative PMD as a function of distance. According to the square law of PMD statistics nature, a small PMD after a high PMD may be hardly distinguished if a measurement uncertainty is too high.

For example, if a 3 ps section is followed by a 10 ps high PMD fiber section, an additional increased PMD value after 3 ps fiber section is only of ~0,44 ps (that is, $\sqrt{10^2 + 3^2} - 10 \approx 0,44$). This requires that the instrument must be able to have a measurement uncertainty better than a few percents.

Secondly according to the PMD theory, a measured PMD (defined as RMS DGD in a given wavelength range) may be varied from one measurement to another because of a PMD theoretical uncertainty due to a finite wavelength range being used; thereby a better accurate measurement may be achieved by using a maximum available wavelength range from the instrument as well as to average over time.

The Advanced testing mode will allow you to improve the measurement.

Basic Verification Steps

Here are some basic verification steps to make sure that your measurement is optimized:

- Make sure that there is not a strong loss at the instrument connector.
- Verify the link length. EXFO recommends optimizing the link length to speed up the acquisition process and make files smaller.
- Verify that there are no big losses along the link. In good conditions, the dynamic of the instrument is around 15 dB. Therefore, do not expect to measure after 15 dB of link loss.
- Verify the scale of the PMD curve, adjust the scale if required.

Use a Larger Number of SOPs and Wavelengths

This will ensure that the instrument can access close to a maximum available wavelength number from the instrument. More SOPs can also improve the measurement accuracy for RMS DGD in the available wavelength range.

A maximum wavelength range and as many SOPs as possible for the acquisition will reduce the uncertainty of a measurement (that is, to achieve a minimum measurement uncertainty).

Note: *At least 100 or 200 SOPs should be used for obtaining a meaningful cumulative PMD curve as a function of distance, and more SOPs. For example, 500 to 1000, is recommended in order to make a better and clearer picture of cumulative PMD.*

Perform Two-Sided Measurements

To make two-sided measurements bring two advantages:

- Nearly doubles a measurement range
- Improves the measurement accuracy.

For example, in a case where a relative small PMD section is followed by a high PMD section, the PMD value of the small PMD section may be difficult to measure accurately, but it may be relatively easy to measure it precisely from another side of fiber under test if there is no very high PMD fiber(s) from there.

By combining two-sided measurements together, you can have a better and clearer cumulative PMD picture with a less measurement uncertainty.

Perform Multiple Measurements

Making multiple measurements over a long time or at different times may be helpful to reduce a fundamental PMD uncertainty if a measured PMD from the FUT is unstable. Using a larger number of SOPs and wavelengths may also result in a long acquisition time that would help to improve the measurement and reduce measurement uncertainty.

Note: *Averaging the measured PMD over time might be helpful to reduce a fundamental PMD uncertainty due to a limited wavelength range.*

Select an Optimized PMD Scale for the Acquisition

Using an appropriate PMD scale is very important. This is because selecting the most appropriate PMD scale regarding the total PMD from an FUT can improve the signal to noise ratio so as to have better measurement dynamics, as well as ensure a signal level that is higher than a coherence noise level.

For example, if the total PMD of an FUT is of 11 ps, an appropriate PMD scale should be of 10 ps, and, if a total PMD of an FUT is of 22 ps, an appropriate PMD scale is of 20 ps.

Note: *Make sure not to select a PMD scale that is too high when measuring low PMD.*

To use an appropriate PMD scale for the acquisition is important for the instrument to obtain a maximum signal level (that is, a mean square transmission difference), thereby to ensure the signal is larger than a coherent noise level. A signal level that is too poor due to a too short beating length in a test fiber section, especially for high depolarization fibers, in comparison with one with a coherence noise level would result in the instrument not being able to measure cumulative PMD correctly along this section of fiber correctly.

Use an Appropriate Residual PMD for the Acquisition

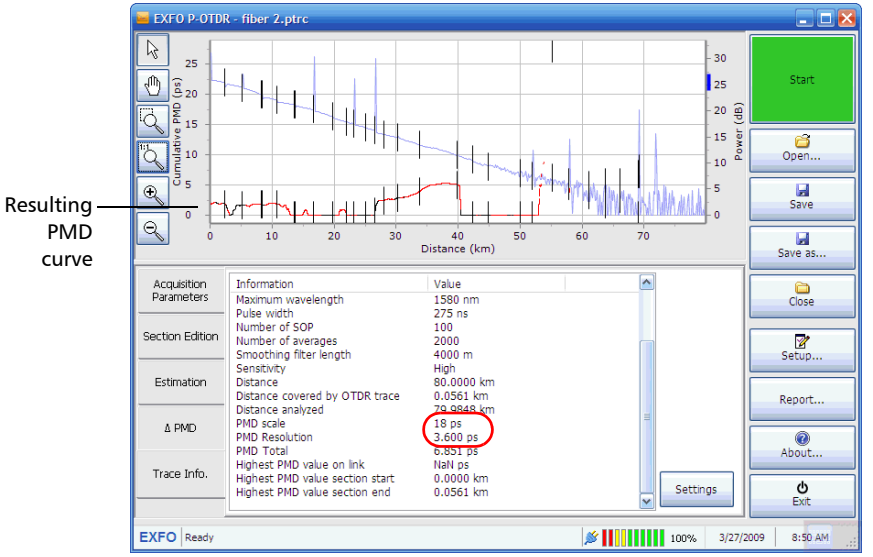
A residual PMD is designed where a limited small PMD value cannot be measured properly. If you want to measure the PMD value on high PMD sections over a few ps and are not interested in low PMD values, for example <1 ps, then you should select a residual PMD that is just smaller than 1 ps.

On the other hand, if you are interested in measuring PMD the value of few hundreds fs, then you should set a residual PMD of less than 100 fs.

Note: *An appropriately selected residual PMD can result in a lower acquisition time.*

More generally, if the PMD curve is very wavy and at the same level as the PMD resolution, then it is the sign of a bad PMD scale. It should be set to a lower value.

The figure below shows an example of a link having a low PMD measured with bad PMD scale and high PMD resolution.



A better setting for this acquisition would have been a PMD scale of 6 ps and a residual PMD value of 133 fs.

Use an Optimized Number of Averagings

The number of averagings is the light pulse averaging used to obtain each individual P-OTDR trace. If you want to have better measurable dynamics, you should select a higher number of averagings. Remember however that this will result in a longer acquisition time.

Should a windy environment or any other reason that causes SOPs to vary over a time period when acquiring each individual P-OTDR trace on an FUT, using a lower number of averagings may be helpful in improving the measurement. However, you will obtain less dynamics.

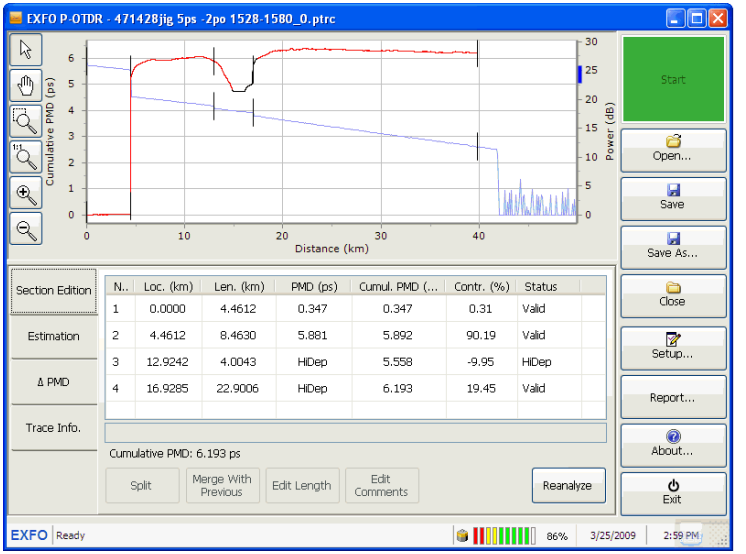
Note: *You should avoid taking the measurement if the light SOP from the FUT varies largely in a time period required for acquiring each individual P-OTDR. An SOP variation that is too high during the time period required for acquiring each individual P-OTDR will result in the instrument not being able to measure the fiber PMD correctly.*

Use an Appropriate OTDR Pulse Length

A recommended pulse length of 100 ns should be used for most acquisitions. However, when a depolarization effect for this pulse may be too big because of short beating lengths from FUTs (that are often observed in the field fibers), a short pulse length, for example, 50 ns, may be used to reduce the depolarization effect and improve SNR so as to ensure an acquired signal level that is larger than a coherent noise level, but it will result in a reduced measurable range.

On the other hand, if the FUT has a small depolarization, use a long pulse length, for example, 275 ns, for the acquisition may be helpful to increase the measurable range or reduce the acquisition time.

Below you can see an example of a depolarization on a fiber:



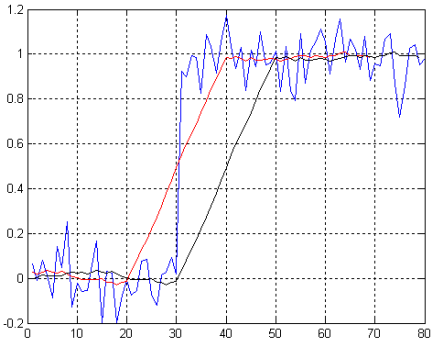
Use an Appropriate Spatial Smoothing Filter Value

The spatial filter for the FTB-5600 was designed to suit the filtering needs of the cumulative PMD curve. The filter preserves sharp transition, which often appears in cumulative PMD measurements; the sharp transition position will not be changed by the filter.

➤ An *anti-causal filter* has the property to remove the delay of the filter from the filtering effect of the signal. This means that it has an effect before the transition occurs.

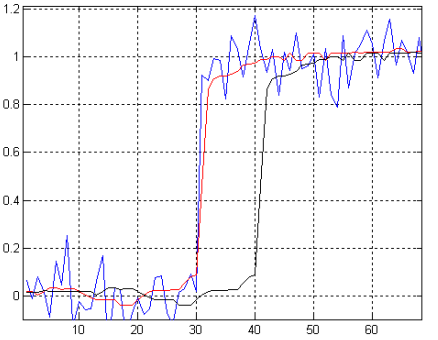
In the example below, we can see the blue curve, which is the raw data, while the black curve is a causal moving average filter and the red one is an anti-causal moving average filter.

Note: *The black and red curves are the same, but the black curve was shifted to the left to remove the delay.*



➤ A *median filter* provides the medium of a group of points. The median filter will preserve sharp transition, whereas the moving average filters will not.

In the figure below, you can see that the sharp transition is still preserved and that there are no delays.

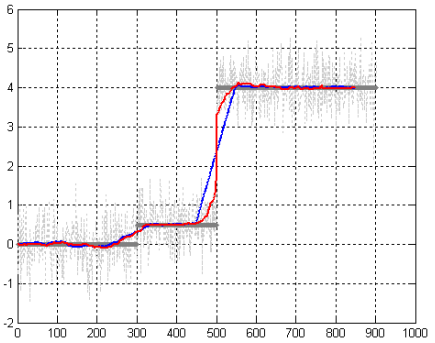


When filtering a cumulative PMD curve, you must take into account the behavior of the filters. You might have to adjust the positions of the markers after you have applied a filter.

In the figure below, you can see how the filter behaves when encountering a small and a large step compared to the noise variance. The red curve is the anti-causal median filter and the blue curve is the causal moving average.

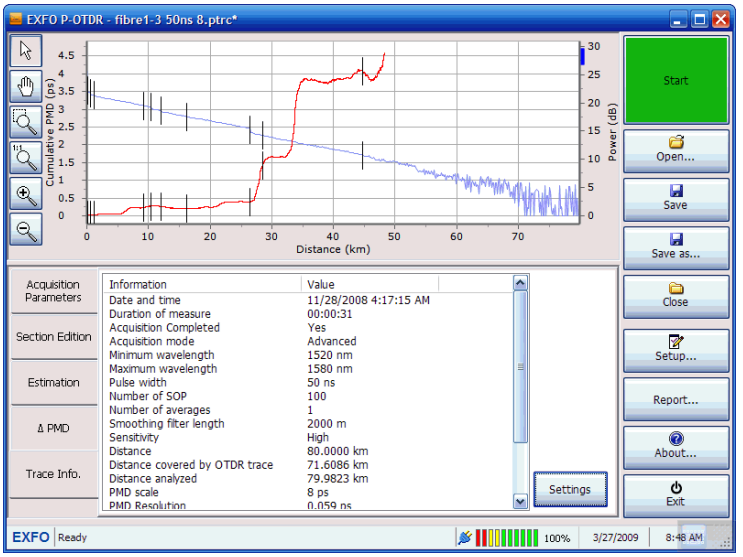
In the case of the small step, the moving average and the median filtering show the same behavior, that is a ramp equal to the filter length to reach the top of the step.

In the case of the large step, the median curve jump almost straight to the top of the step, whereas the moving average will show a different appearance.



Below is an example of applying different filter values to a same trace. The first curve has a filter of 100 m applied to it. The noise is quite visible and the PMD changes are sharp. Attempting to take measurements on this trace without a filter is not recommended, as there is too much noise.

If a 2000-m filter is applied to the curve, you can see a noticeable improvement. The noise level is much lower, yet the PMD variations are still there. This is the best filter value for such a trace.



If you use a filter value that is too high, in the case below, 8000 m, you can notice that there are not enough values to make proper measurements. It would still be possible, but placing the markers in the exact positions is very difficult as the flat section in the middle is not very clear.

The anti-causal filter has an effect on the PMD curves; it will cause them to end before the actual end of the fiber. With a correct dynamic range, the cumulative PMD curve ends halfway through the actual fiber length.

Use a Receive Fiber

If you want to take measurements at the end of the link, you must add a receive fiber of at least the length of the filter you are using. For example, if you use a spatial filter of 4000 m, you will need a 2000-m receive fiber.

Note: *The receive fiber should have a low PMD and long beating length to help you with your measurements.*

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NOTICE

通告

CHINESE REGULATION ON RESTRICTION OF HAZARDOUS SUBSTANCES

中国关于危害物质限制的规定

NAMES AND CONTENTS OF THE TOXIC OR HAZARDOUS SUBSTANCES OR ELEMENTS CONTAINED IN THIS EXFO PRODUCT

包含在本 **EXFO** 产品中的有毒有害物质或元素的名称和含量

O	Indicates that this toxic or hazardous substance contained in all of the homogeneous materials for this part is below the limit requirement in SJ/T11363-2006 表示该有毒有害物质在该部件所有均质材料中的含量均在 SJ/T11363-2006 标准规定的限量要求以下。
X	Indicates that this toxic or hazardous substance contained in at least one of the homogeneous materials used for this part is above the limit requirement in SJ/T11363-2006 表示该有毒有害物质至少在该部件的某一均质材料中的含量超出 SJ/T11363-2006 标准规定的限量要求。

Part Name 部件名称	Toxic or hazardous Substances and Elements 有毒有害物质和元素					
	Lead 铅 (Pb)	Mercury 汞 (Hg)	Cadmium 隔 (Cd)	Hexavalent Chromium 六价铬 (Cr VI)	Polybrominated biphenyls 多溴联苯 (PBB)	Polybrominated diphenyl ethers 多溴二苯醚 (PBDE)
Enclosure 外壳	O	O	O	O	O	O
Electronic and electrical sub-assembly 电子和电子组件	X	O	X	O	X	X
Optical sub-assembly[a] 光学组件 [a]	X	O	O	O	O	O
Mechanical sub-assembly[a] 机械组件 [a]	O	O	O	O	O	O

a. If applicable.
闆稙骀钐祤塞粒粒。

MARKING REQUIREMENTS
标注要求

Product 产品	Environmental protection use period (years) 环境保护使用期限 (年)	Logo 标志
This Exfo product 本 EXFO 产品	10	
Battery[a] 电池 [a]	5	

a. If applicable.
闆稚骀钐裰塞粒。

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Printed in Canada (2009-06)

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