LUCIOL INSTRUMENTS

LOR-200/220

LOR-200/220
User’s Manual

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1 Introduction

This manual gives an overview of the LOR-200/220 High Resolution OTDR from Luciol Instruments. This instrument is based on a new scanning photon-counting technique (patent pending). Photon-counting detectors, in contrast to classical analog detectors, achieve at the same time a very high sensitivity and a very high resolution. It is this dual advantage, speed and sensitivity, which provides the LOR-200/220 with its unique properties. Luciol's expertise in photon counting technology makes this technology available for portable optical test instruments which can outperform their classical analog counterparts.

The high resolution makes the LOR-200/220 an ideal instrument when it comes to testing short-range optical networks and links. Typical examples are Local Area Networks (LAN) or optical fiber links inside buildings, cars and planes. Here, the optical spans are typically in the tens to hundreds of meters range. But the LOR-200/220 can even analyze fiber spans up to 160 km. In addition, a high resolution "zoom" function allows identifying events which are invisible for standard OTDRs. The user can set this zoom to any region of the fiber under test.

You can measure the distributed attenuation along the fiber, to check for example the homogeneity of your fiber. You can discover and identify damages, which may have occurred during the laying out of your fiber (bends, pressure points...). You can see losses and backreflections from connectors or optical components.

The LOR-200/220 is a simple and easy-to-use instrument, with user-friendly GUI software. We provide a standard, versatile software, which should suit your particular needs. In case your application requires additional features, please contact Luciol Instruments. We are ready to examine with you any special software and hardware requirements.

In addition to the User's Manual, we can provide a number of Application Notes, which explain how to perform several types of measurements. Visit our web site www.luciol.com to download the latest version.

1 Quick Guide

This quick guide section is a simple step-by-step approach to optical fiber testing with the LOR-200/220. You should read it if you need to learn how to operate the instrument quickly. You may then read the other sections as needed.

1.1 Operating instructions

The OTDR unit is integrated into a PC-based platform, operating under Windows® 7. The platform is designed for field use, with a bright touchscreen display.

1) Start the instrument by pressing the red on/off button for at least 1 second. The LOR-200/220 application software is already installed and will be launched automatically after the operating system has been loaded.
2) Open the ***Settings*** tab and select all the required measurement settings. In many cases the defaults settings can be used for an initial test of a fiber.
3) Connect the Fiber Under Test (FUT) to the unit, and click the START button to start the measurement. The OTDR status is displayed in the black bar on top. The status display will show *scanning* while an OTDR trace will build up from the selected start-position until it reaches the selected end-position.
4) The measurement can be interrupted at any time by clicking on the STOP button.
5) Save a measured trace by clicking FILE – SAVE AS.
6) Load a previously saved trace by clicking FILE - LOAD TRACE 1 or LOAD TRACE 2.

1.2 Notes

Help

The software includes a context help function. Activate context help by clicking HELP - CONTEXT HELP, or by pressing Ctrl H. A help window will now open. Move the cursor to the feature for which you wish to receive help. The feature will now be briefly explained in the help window.

Fiber Preparation

Due to the high sensitivity of the photon-counting detection, care has to be taken to avoid any stray light entering the fiber under test. For SMF and standard MMF (i.e. 50 or 62.5 µm core), avoid any strong light on the unit or the fiber under test. For large core MMF or plastic optical fibers, any open end should be covered, and the fiber should have an opaque jacket. All optical connector interfaces must be kept dust free and be cleaned regularly.

2 Hardware Overview

2.1 The Front Panel

Figure 1 shows the front panel of the LOR-200/220. The front panel contains the LCD-touchscreen, the hardkeys (see box on the right) and two LED indicators.

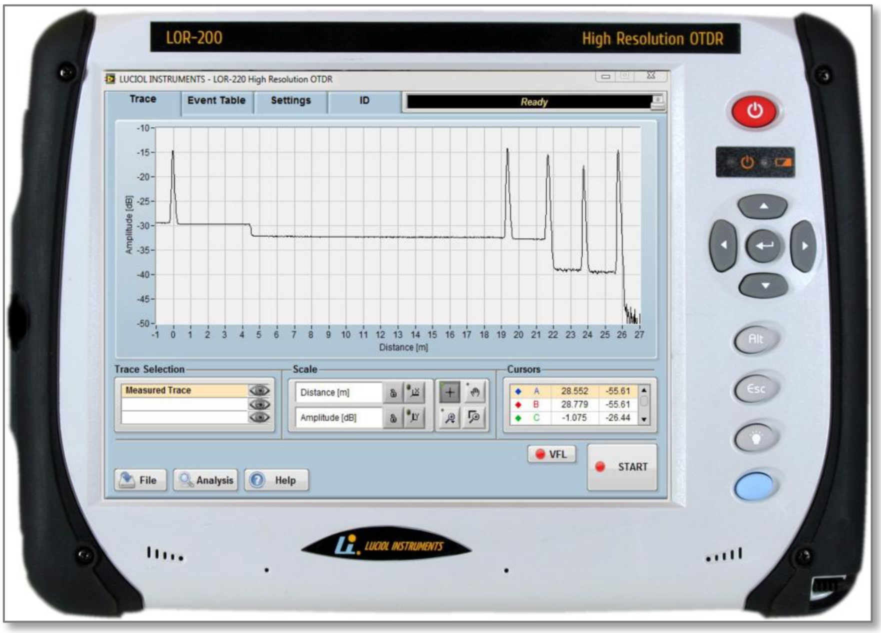


Figure 1: The Front Panel

Hardkeys functions

(**Red Key**) Power the instrument on

(▶ ▲ ▼ ◀) Move markers or cursors, scroll through menus

(**↵**) Executes selected action

(**Alt**) Highlight menu access

(**Esc**) Escape from current action or selection

( ) Set the display brightness

(**Blue Key**) Start a measurement or call the help menu

The touchscreen should only be used with the stylus, which is inserted on the lower right hand side of the unit, or with the fingers. A touch on the screen is equivalent to a standard click with a mouse on the corresponding point. In order to perform a right click with the touchscreen, press the stylus for a few seconds on the screen, until the right click menu appears.

> **Important:** The use of any sharp object, such as ball point pen or metal tool on the touchscreen will damage it, and voids the warranty.

2.2 The Optical Port

Figure 2 shows the optical port of the LOR-200/220. It is located on the top of the instrument. Before attaching a fiber you should clean it using an appropriate cleaning method. Contact Luciol Instruments if you need assistance. Make sure the attached fiber and the instrument connector interface are of the same type. Never connect an angled connector (APC) to a flat connector (PC).

Figure 2: The Optical Port

Note: Some instruments are equipped with an interchangeable optical connector. The outer part of this connector can be removed to adapt the instrument to different types of connector interfaces. Contact Luciol Instruments for more information on the available interface types.

2.3 The Communication Ports

Figure 3 shows the communication ports of the LOR-200/220. They are located on the left side of the instrument.

The following interfaces are provided:

← Serial port connector

← Video connector (external monitor)

← USB 2.0 connectors (2x)

← Network connector

Figure 3: The Communication Ports

2.4 The Power Connector

Figure 4 shows the DC power connector of the LOR-200/220. It is located on the right side of the instrument.

Connecting the power:

Plug the round female connector from the external power adapter into the instruments power connector.

Plug the two-pin female connector on the power cord into the power adapter.

Plug the standard electrical plug from the power cord into your AC source (100 to 240 VAC, 50/60 Hz universal adapter).

> **Important:** The power adapter may become rather hot after prolonged use. This is normal, and does not affect the performance of the device. Only use the Luciol Instruments power supply (part no. SS138D-Jack).

Figure 4: The DC Power Connector

2.5 Charging the Battery

The LOR-200/220 has a built-in charger. Battery charging will start automatically (operating or none operating) when the instrument is connected to the external power supply. The charge indicator (LED next to the battery symbol in Figure 5) will light when a power supply is present.

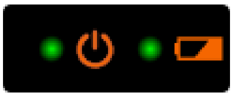


Figure 5: The Battery Charge Indicator

Charge Indicator	Charge Status
OFF	No external power supply
RED	Charging
GREEN	Fully charged, external power supply connected

Detailed information on the charge status can also be obtained from the battery manager software tool described in section **Error! Reference source not found.**.

Note: A charged battery will gradually lose its charge if left in storage. It is therefore good practice to recharge the battery every 1-2 months during storage.
If the LOR-200/220 is not used for a long period of time, it is recommended to connect the external power supply and start a charging cycle prior to switching on the instrument.

2.6 Changing the Battery

The battery should be inserted in the slot at the foot of the LOR-200/220. Figure 6 shows the back of the LOR-200/220 with the battery slot opened. Use a screwdriver to unlock the two screws of the battery slot and remove the cover.

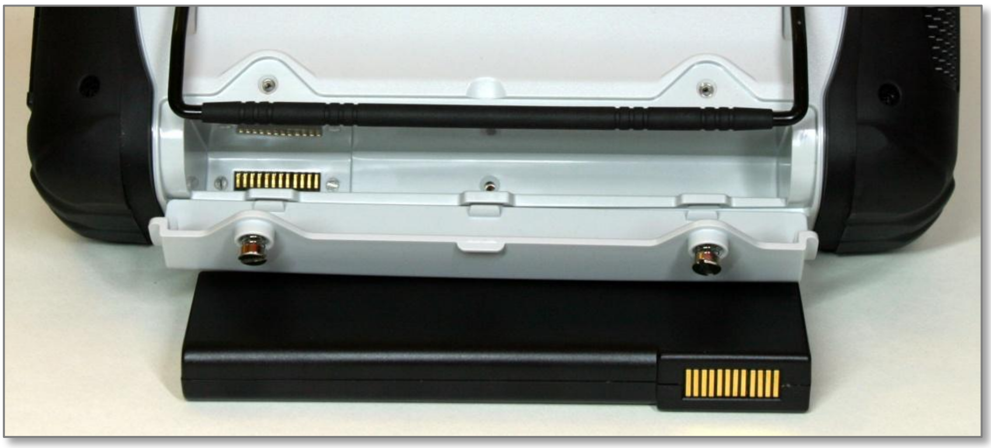


Figure 6: The Battery Slot

Important: Do not insert the battery while operating the instrument.
Do not short circuit the battery by connecting the metal terminals.
Do not expose the battery to fire or high temperature.
Make sure you insert the battery in the correct direction and that the slot is closed correctly.
Only use the Luciol spare battery pack (part no. BAT-LOR200).
The battery is a consumable part and is not subject to the LOR-200/220 warranty.

3 Software Tools

3.1 The On-Screen Keyboard

If no physical keyboard is attached to the instrument, launch the on-screen keyboard from the task-bar to type and enter data.

Figure 7: Using the on-screen keyboard

More information can be found in the *Tools - Help Topics* menu from the on-screen keyboard.

4 OTDR Software Overview

When the unit is switched on, the OTDR software is launched automatically, and the user interface appears as shown in Figure 8. The black status indicator shows the actual status of the instrument and gives basic usage instructions. It will display *Ready* when the application is launched and a connected OTDR is found.

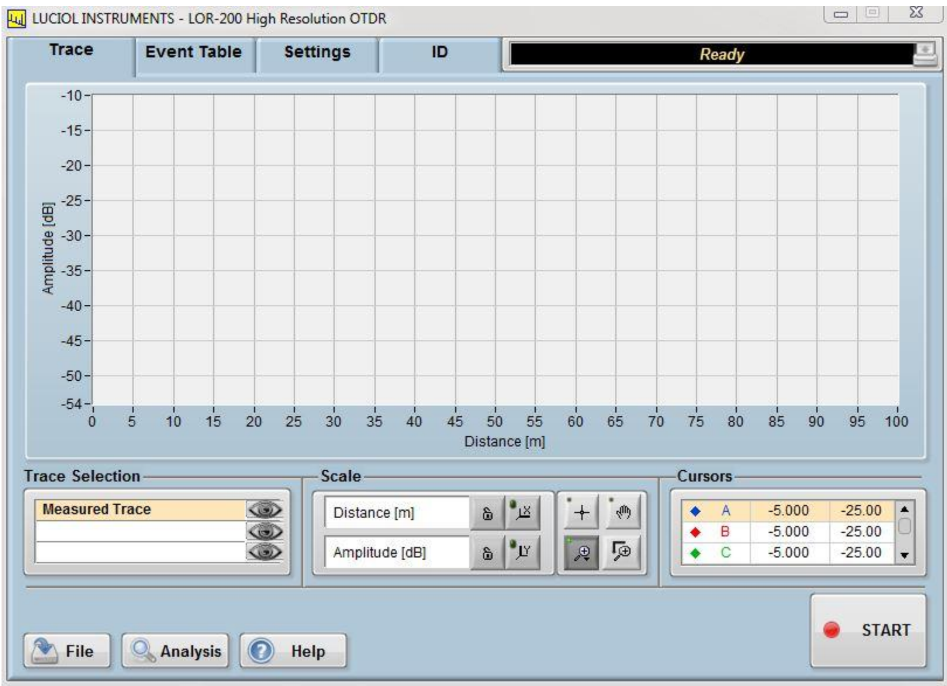


Figure 8: The LOR-200/220 user interface after starting

The LOR-200/220 software is written in Labview®. A detailed description of the software functions is given in the following sections.

4.1 The Menu Functions

4.1.1 The File Menu

Clicking FILE opens the file menu:

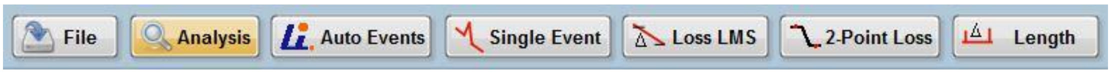
Here you can:

- Load one or two previously saved traces
- Save the data as a text file (*.tor), this file can later be opened with any text editor or spreadsheet application. For LOR-200 systems the data can also be saved as a standard OTDR (*.sor) file (SR-4731 standard).
- Generate a report in HTML or PDF format.
- Close the application

Click FILE again to close the menu.

4.1.2 The Analysis Menu

Clicking ANALYSIS opens the analysis menu:



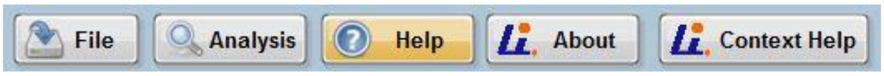
From the analysis menu you can select several types of trace analysis functions:

- AUTO EVENTS for automatic detection of all events in the trace
- SINGLE EVENT for semi-automatic characterization of single events
- LOSS LMS for manual fiber loss measurements
- 2-POINT LOSS to measure directly the loss between two positions in the fiber under test
- LENGTH for high precision length measurements between reflective events

The events can be added to the event table. These features will be discussed further in section 5.

4.1.3 The Help Menu

Clicking HELP opens the help menu:



With this menu, you can get explanations about the various features of your measurement window. Click on CONTEXT HELP, or use Ctrl+H, to open the help window. Move the cursor around to see the explanations on the various features of the measurement window. By selecting ABOUT, you can also get information about the current software.

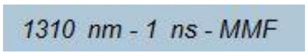
4.2 The Tabs

4.2.1 The Trace Tab

The ***Trace*** tab is the main application control tab, as shown in Figure 8. Besides the OTDR trace indicator it contains:

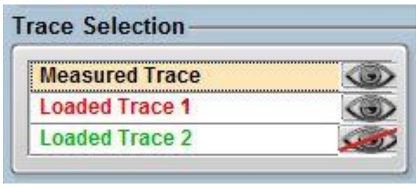
- The START/STOP control for starting and stopping a measurement manually.

- The wavelength and pulse-width indicator for the active measurement.



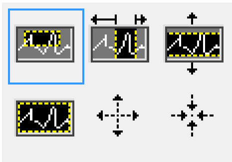
- This indicator is replaced by the trace analysis bar when a manual analysis function is selected.

- The Trace Selection legend: The highlighted trace (orange) is the active trace e.g. for the trace analysis functions. Click on the trace name to change the active trace. With the eye-checkboxes on the right you can choose if a trace is shown or hidden.



- The Scale legend and graph palette: Click on the X or Y axis symbol to auto-scale the corresponding axis. Click on the lock symbol to lock and unlock auto-scaling.

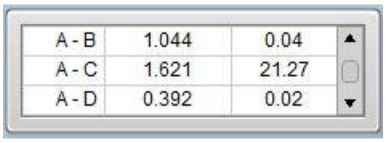
    - The graph palette contains the cursor positioning tool (top left), the zoom and the undo zoom tools (bottom), and the hand tool (top right). Click on the corresponding tool to activate it.
    - The zoom tool has several functions; a sub-menu as shown on the right will open when clicking on it. The selectable zoom options are window zoom, vertical zoom and horizontal zoom, zoom the entire trace, zoom in and zoom out.



Note: To apply a zoom, auto-scale needs to be unlocked

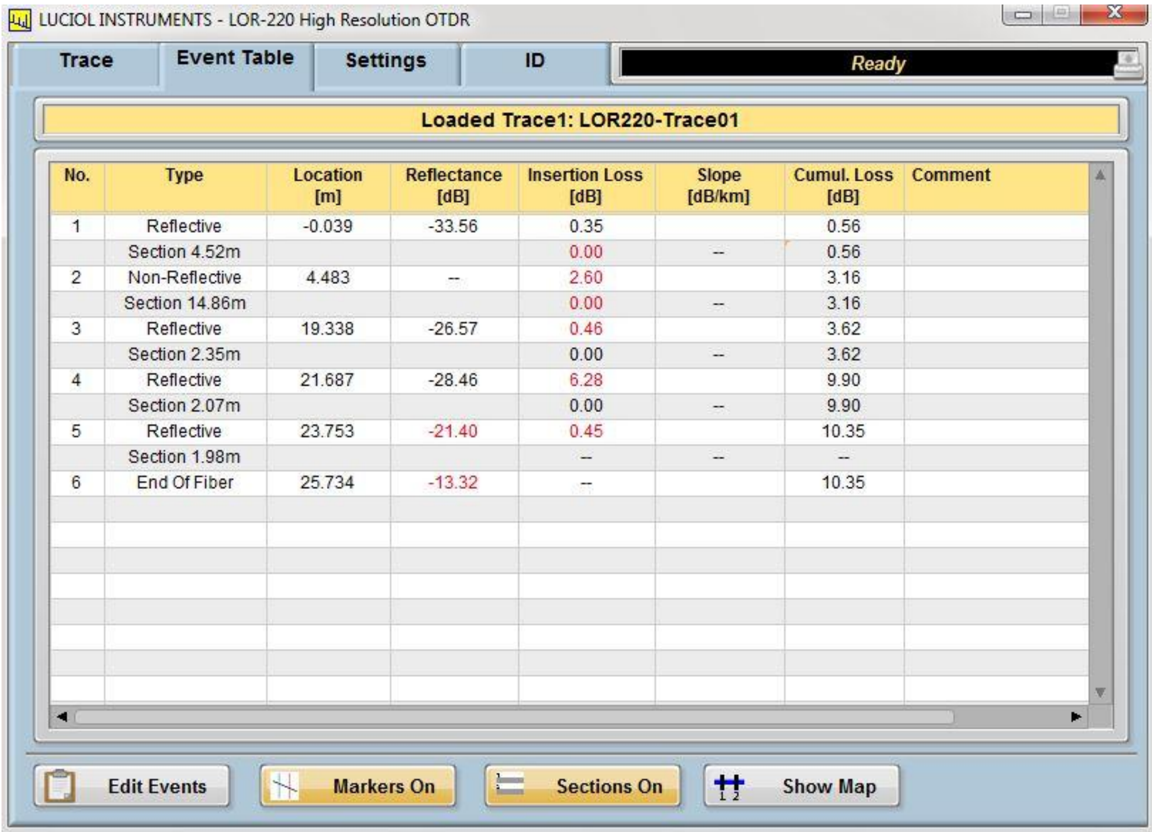
The hand tool allows moving the entire trace within the graph.

- The Cursors legend: This window provides the cursor legend and the cursor position indicators. The active cursor is highlighted (orange). This cursor can also be positioned using the arrow keys from the key pad. Click on the cursor row to change the active cursor. A double-click on a row will bring the corresponding cursor to the center of the window. Cursor distance information can be found when scrolling further down in the list.



4.2.2 The Event Table Tab

The ***Event Table*** tab lists all manually or automatically found events. An example is shown in Figure 9.



No.	Type	Location [m]	Reflectance [dB]	Insertion Loss [dB]	Slope [dB/km]	Cumul. Loss [dB]	Comment
1	Reflective	-0.039	-33.56	0.35		0.56	
	Section 4.52m			0.00	--	0.56	
2	Non-Reflective	4.483	--	2.60		3.16	
	Section 14.86m			0.00	--	3.16	
3	Reflective	19.338	-26.57	0.46		3.62	
	Section 2.35m			0.00	--	3.62	
4	Reflective	21.687	-28.46	6.28		9.90	
	Section 2.07m			0.00	--	9.90	
5	Reflective	23.753	-21.40	0.45		10.35	
	Section 1.98m			--	--	--	
6	End Of Fiber	25.734	-13.32	--		10.35	

Figure 9: The event table tab

In order to edit the event table manually, click EDIT EVENTS.

The MARKERS ON/OFF button allows showing or hiding the event markers on the trace.

Select SECTIONS ON to display the length and the losses of the fiber sections between the events.

Clicking SHOW MAP will display a graphical representation of the fiber under test and the events (Figure 10). The image can be added to the report using the REPORT tool.

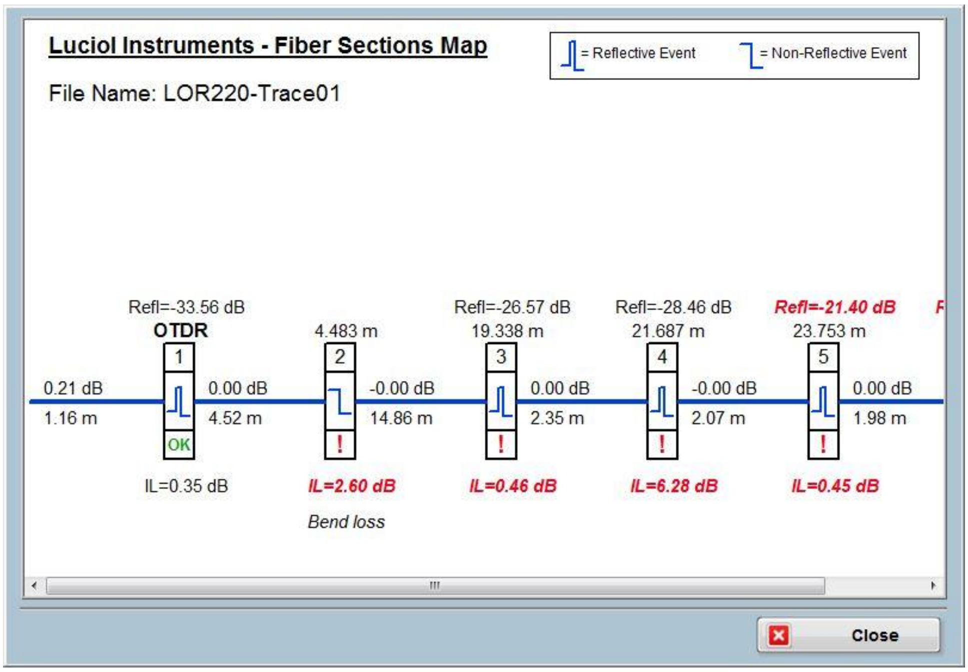


Figure 10: The event map

4.2.3 The Settings Tab

The ***Settings*** tab as shown in Figure 11 is used to set the required parameters for a new trace (measured trace), or to display the settings of a loaded trace (the **active trace** selected in the trace selection window of the ***Trace*** tab is shown).

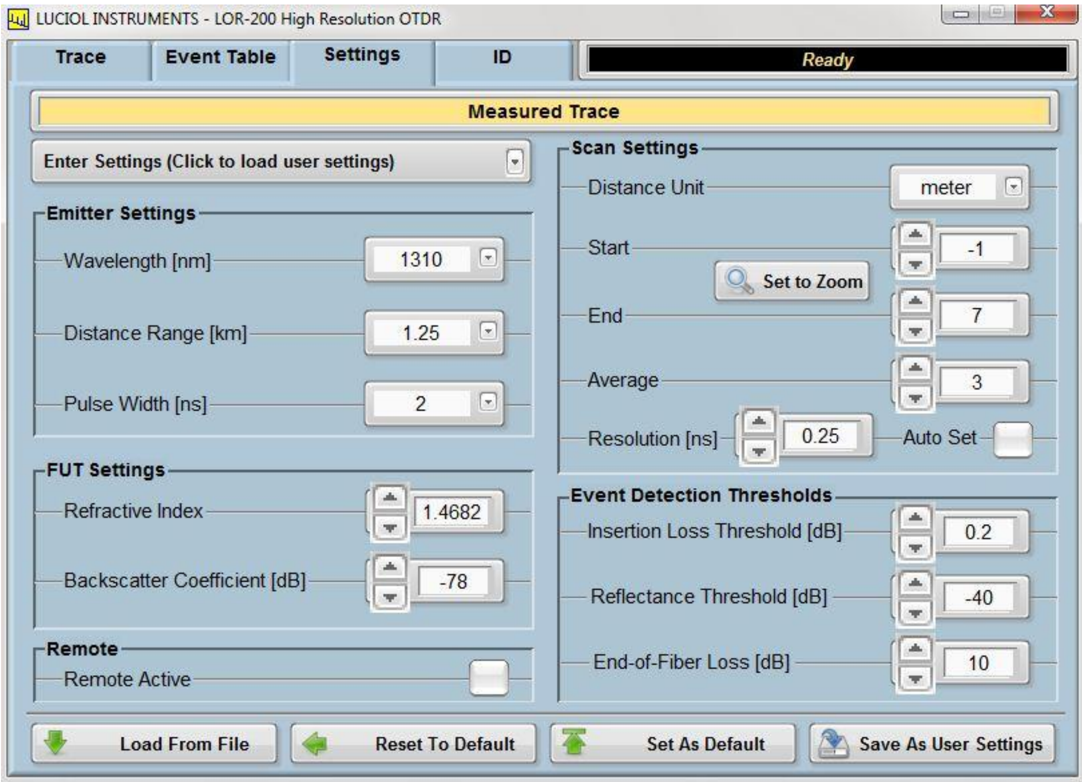
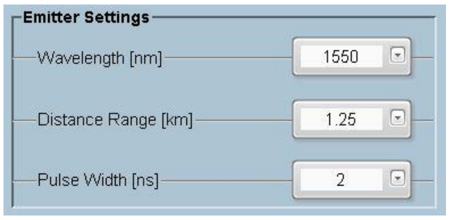


Figure 11: The settings tab

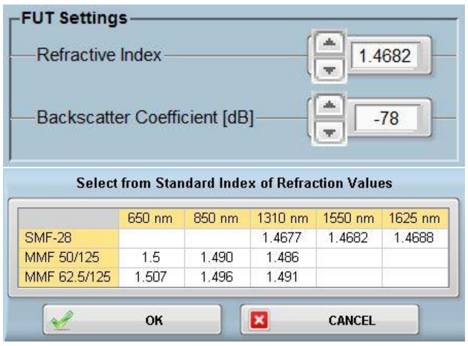
There are five groups of settings:



- The ***Emitter Settings*** group is used to select the emitter to be used for the current measurement. For multi-wavelength systems the wavelength can be chosen from a list of available emitters. The second control sets the distance range (the maximum length, the fiber under test must not exceed). The third control sets the optical pulse-width of the emitter. A single click on the number will open a list with the available settings.

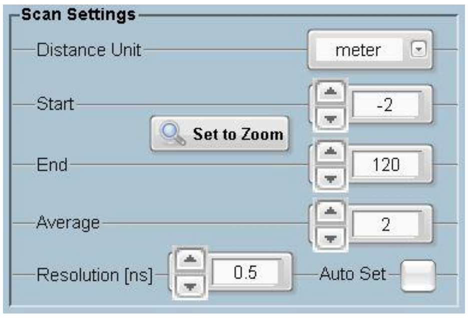
Notes:
The distance range has to be superior to the total length of the fiber under test, even if you wish to observe only a short distance.
The high resolution model LOR-220 is working with a fixed pulse-width of 1 ns and there is no pulse-width control.

- The *FUT Settings* group allows selecting the refractive index, and the Rayleigh back-scattering coefficient. Both parameters may vary according to the wavelength and fiber type, and should be obtained from the datasheet of the FUT†. A right-click on the refractive index indicator will open a table containing standard values. Click on the value corresponding to the fiber under test and click OK to use a standard refractive index.

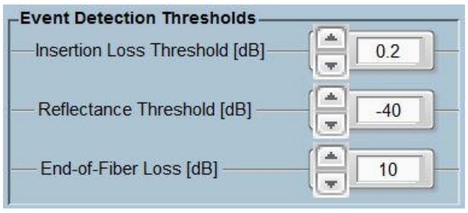


- *Remote*: The unit can be remotely controlled via Ethernet. When the Remote Active check box is selected, the instrument will wait for a remote connection. Contact Luciol Instruments for details.

- The *Scan Settings* group allows choosing the distance unit (available options: are meter, kilometer, feet, miles, and nanosecond); the Start and Stop positions for the scan, the average and the resolution (step size). The Set to Zoom button allows setting the Start and the End position automatically to the currently zoomed trace section in the *Trace* tab. The average control sets the number of averages at each measurement point. Higher averages will lower the measurement noise and smoothen the trace, but will increase the measurement time, as each measurement point will take more time. The resolution control sets the step size between each measurement point. In general this size should be smaller than the pulse-width. If the Auto Set checkbox is enabled, the resolution is automatically set to about ¼ of the pulse-width. The minimum step size (resolution) is 0.25 ns.



- The *Event Detection Threshold* group allows the selection of the thresholds used for the automatic detection of events. The insertion loss threshold chooses the maximum allowed insertion loss of an event. The reflectance threshold does the same for reflections. After the cumulative loss of the fiber assembly under test exceeds the end of fiber loss threshold the automatic event detection is stopped and the last detected event is set as the end of fiber event (see section 5.2.7 for details).

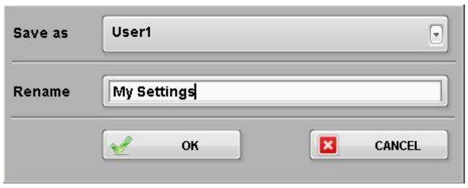


Hint: A double click on most controls of the *Settings* tab will open a numeric keypad which simplifies the data entry.

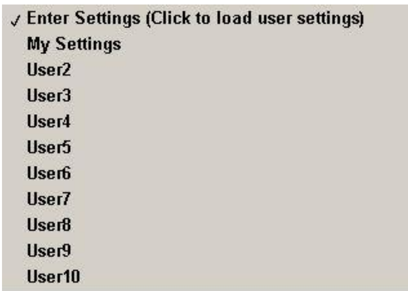
† For precise return loss measurements it is recommended to measure the Rayleigh backscattering coefficient with the OTDR. See section 5.1.3 for details.

4.2.3.1 Saving and loading user defined settings

The user can save the current settings by clicking Save As User Settings. This will open a dialog window as on the right. Up to 10 different user-settings can be defined this way.



To re-load one of the user-settings, click the ring control Enter Settings (Click to load user settings) and select one of the settings from the list as on the right.



User settings can also be loaded from a previously saved measurement by clicking Load From File. Select a measurement file from the pop-up dialog from which you want to copy the measurement parameters.

Default measurement parameters can be defined and loaded using the Set As Default, or the Reset To Default button.

4.2.4 The ID Tab

The ***ID*** tab is shown in Figure 12. The various fields in this tab allow you to add the relevant information to the stored trace for identifying the fiber under test.

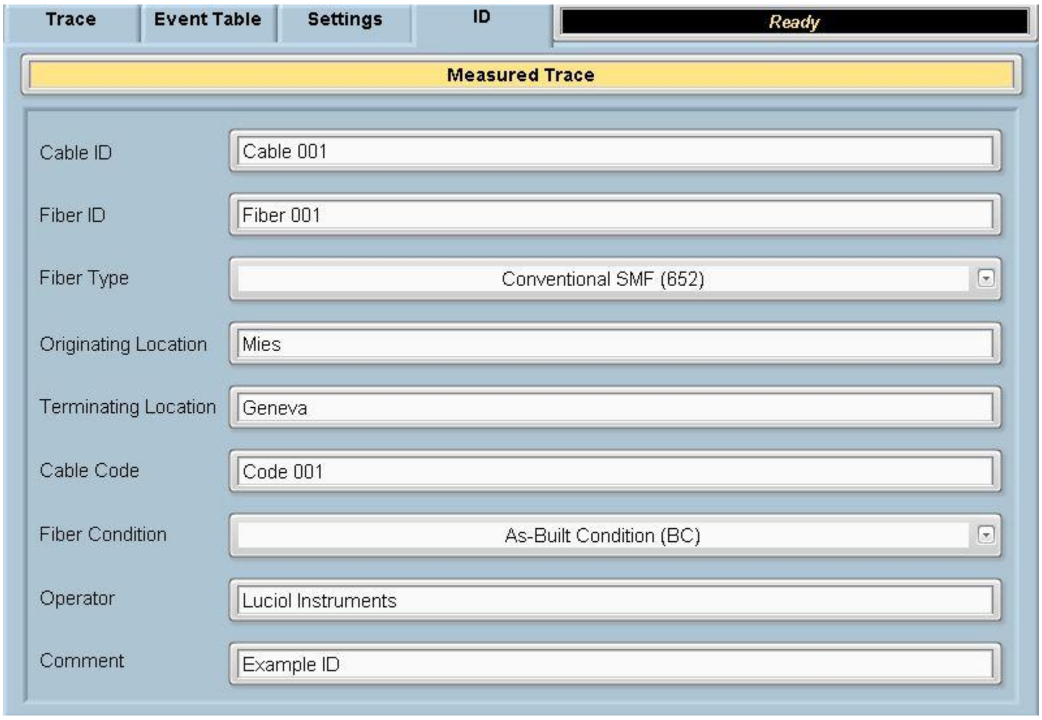


Figure 12: The ID tab

5 Making Measurements

5.1 General measurement setup

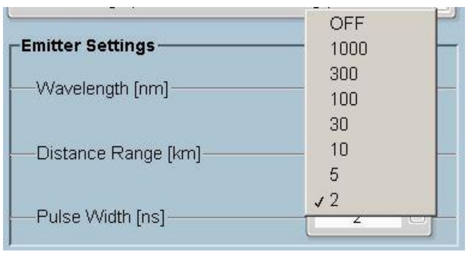
Make sure that all connectors are clean. Connect the FUT to the OTDR.

> **Important:** The photon-counting detection system is highly sensitive, and can therefore be perturbed by any stray light in the FUT. For single-mode fiber the amount of stray light entering the fiber is minimal. The problem is more serious with multi-mode fiber, and especially large core fibers. In this case, any fiber end should be covered, and the fiber should have an opaque jacket. If this is not possible, we recommend working in a darkened environment.

Click on the ***Settings*** tab (see 4.2.3), and set all controls to the required values. For fiber identification fill out the fields in the ***ID*** tab (see 4.2.4).

Go back to the ***Trace*** tab, and start the measurement by clicking on the START button. The OTDR starts the scan, and will make a measurement step by step with a step width corresponding to the selected resolution. The scan will stop when the selected End position is reached. The scan can also be interrupted by pressing the STOP button. Click FILE – SAVE AS to save the measured trace.

5.1.1 Setting pulse-width and resolution



The LOR-200 allows 7 different pulse-width settings; a list with all available values opens after clicking on the currently selected value as shown on the right. For the LOR-220, the pulse-width is fixed to 1 ns.

The optimal pulse-width depends on the type of measurement, the length of the fiber under test and the required spatial resolution. In general, the longest pulse-width providing a sufficient spatial resolution should be selected. The Rayleigh- backscattering level is proportional to the pulse-width; therefore the OTDR traces will become less noisy when increasing the pulse-width. At the same time the dynamic range of the OTDR will increase. An example is shown in Figure 13. The lower red trace was recorded using a pulse-width of 2 ns while the upper black trace was recorded using a pulse-width of 1000 ns. For both traces the resolution was set to 0.5 ns and the average to 1. Using 1000 ns pulse-width the measured RBS level and the dynamic range increase by about 14 dB and the trace is less noisy.

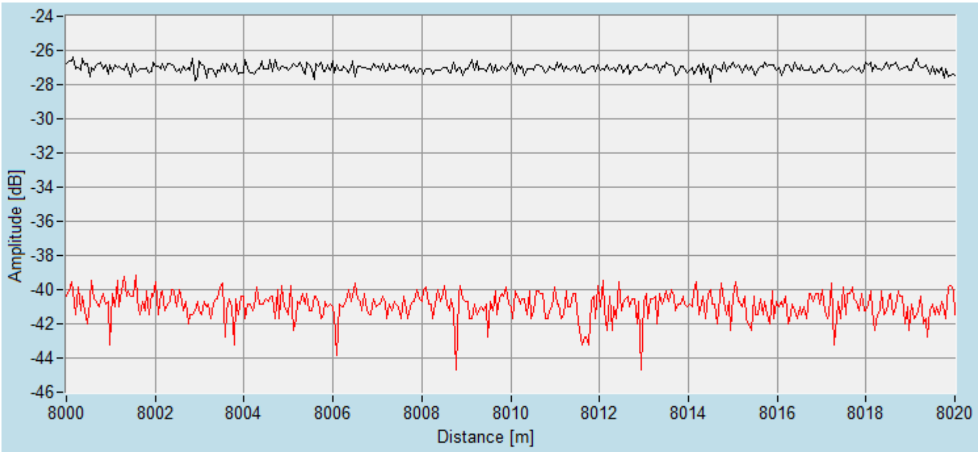


Figure 13: RBS signal at 2 ns pulse-width (red) and 1000 ns pulse-width (black).

The resolution determines the number of samples recorded for the trace. A higher resolution setting will result in a more detailed trace but will also increase the measurement time. The resolution of the LOR-200/220 can be set in steps of 250 ps. The minimum value is 250 ps; corresponding to approximately 2.5 cm. The resolution should always be set to a value smaller than the pulse-width. The auto-set function will set the resolution to approximately ¼ of the pulse-width. Setting the resolution to a value bigger than the pulse-width may lead to incorrect measurements of the reflectance and some reflective event may not be correctly displayed.

An example is shown in Figure 14. Three fiber patch-cords of 5 m length are connected to the OTDR. All traces are measured with 10 ns pulse-width. The red trace is recorded with the automatically set resolution of 2.5 ns, the black trace is recorded with the highest resolution of 0.25 ns, and the green trace with a resolution of 10 ns.

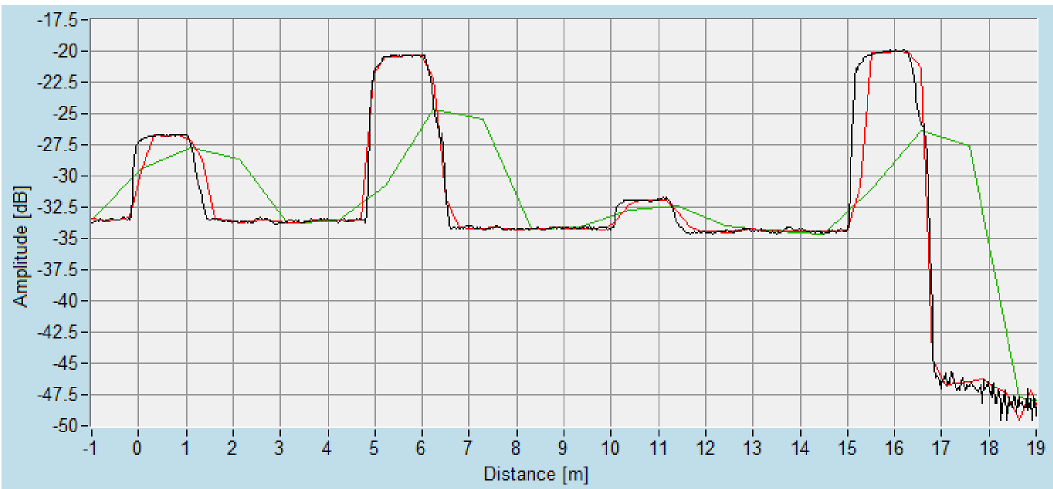


Figure 14: Setting the resolution

Setting the resolution to 10 ns (green) allows obtaining a quick overview of the trace but the resolution is not sufficient for a correct measurement of the reflectance levels. The red trace with 2.5 ns resolution correctly displays the peak amplitudes and the dead zone is sufficiently small for insertion loss measurements. Using the highest resolution (black) slightly further decreases the event dead zone and the position of the rising edges of all peaks can be found with higher precision. Using the highest possible resolution is therefore recommended for exact measurements of the fiber length.

A good choice for testing the three fiber setup would therefore be a pulse-width of 10 ns and a resolution of at least 2.5 ns (or better, if the length of the fibers needs to be tested). A pulse-width of 30 ns would also be sufficient and increase the dynamic range. A comparison of two measurements using 10 ns and 30 ns pulse-width is shown in Figure 15. Both traces are recorded with a resolution of 1 ns.

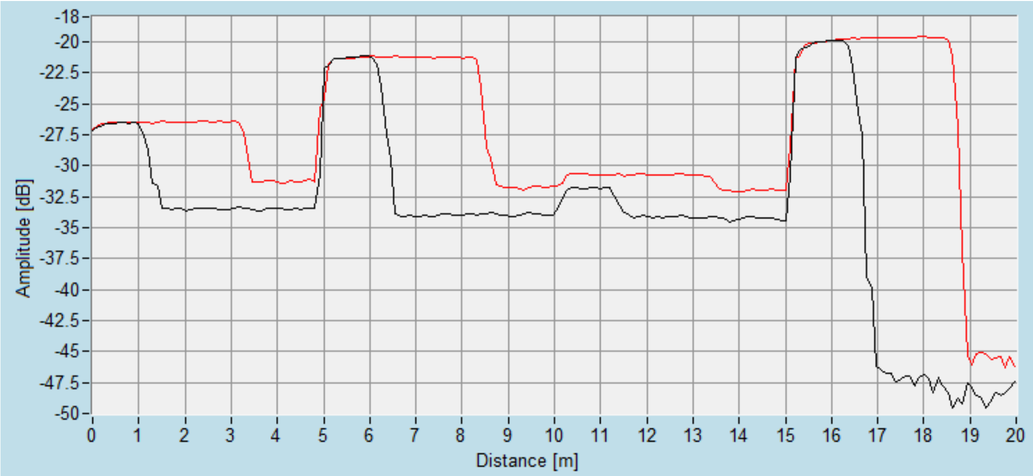


Figure 15: Setting the pulse-width

5.1.2 Setting the index of refraction

An OTDR measures the elapsed time between the emission of a laser pulse and the arrival time of a backscattered photon. To convert the measured time into the displayed distance unit, the index of the refraction of the fiber under test needs to be known. Especially for precision measurements of the fiber length, a correct value of the index of refraction is important. The index of refraction depends on the fiber type and the wavelength and it also varies with ambient conditions like strain and temperature. Some typical values are listed in Table 1.

Table 1: Recommended group index of refraction‡

Fiber Type	650 nm	850 nm	1310 nm	1550 nm	1625 nm
SMF-28			1.4677	1.4682	1.4688
MMF 50/125 µm	1.5	1.490	1.486		
MMF 62.5/125 mm	1.507	1.496	1.491		

For other fiber types, please contact the fiber manufacturer. It is also possible to measure the index of refraction with the LOR-200/220. For a high accuracy measurement, a reference fiber whose length is precisely known is required. Measure the length of this fiber using the LENGTH function from the analysis menu (see section 5.2.4) and vary the index of refraction until the measured length is equal to the calibrated length.

> **Note:** When starting the OTDR, the index of refraction will be set to its default value of 1.4682 or to the value set in the previous session.

‡ Source: Corning Cable Systems (850-1625 nm)

5.1.3 Setting the Rayleigh backscatter coefficient

The Rayleigh backscatter coefficient is the backscattered power from the fiber under test relative to the peak power of a 1 ns laser pulse emitted by the OTDR. For many standard fibers and wavelength this parameter can be found in the data sheet of the optical fiber under test.

For special fibers and wavelength this value is hard to find, or sometimes the manufacturer's values are not reliable. For precise return loss (reflectance) measurements we recommend to measure this value directly with the OTDR. Since the Rayleigh backscatter coefficient is used as the reference level for reflectance measurements it is important to set this level properly.

Make a measurement with the following settings (no fiber connected to the OTDR):

- Set the wavelength to the test conditions
- Set the pulse-width to the required test conditions
- Set distance range to 1.25 km
- Set Start to -2 m, End to 2m
- Set Average to 4
- Set Resolution to 0.25

Start the measurement and wait until the test has finished. Got to: ANALYSIS – SINGLE EVENT. Set the markers and make a zoom to find the Rayleigh level between -2 m and 0 m (see Figure 16).

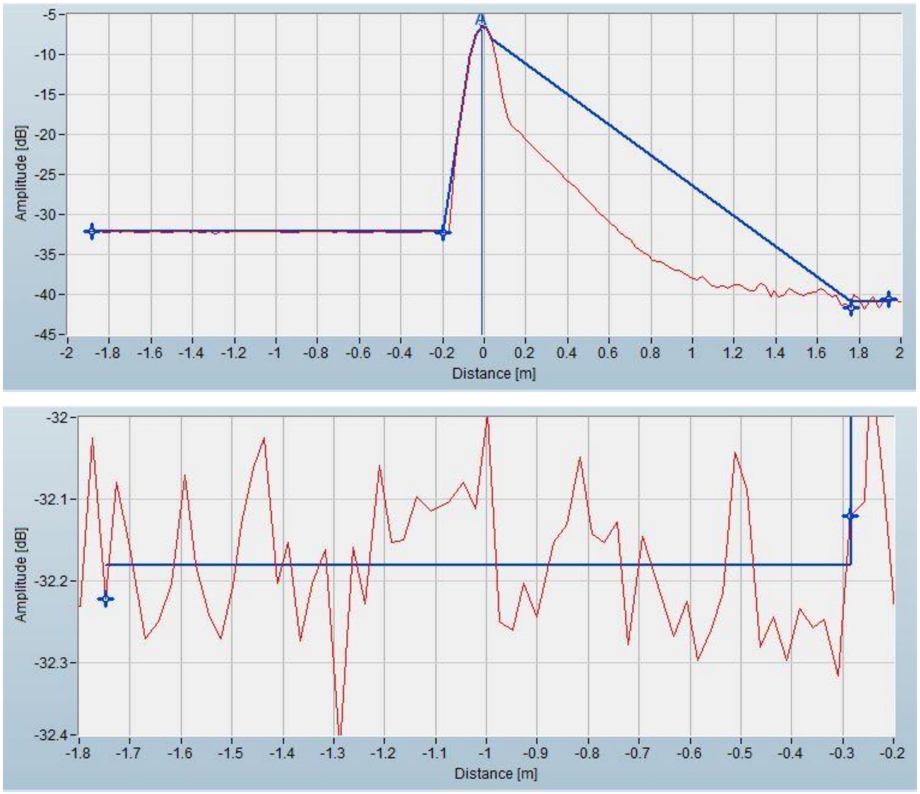


Figure 16: Setting the Backscatter Coefficient

Here the level is about -32.2 dB. The Rayleigh backscatter coefficient is the double of this value for a pulse-width of 1 ns (LOR-220). The correct setting in this example would be -64.4 dB.

If the OTDR is operated with a pulse-width different from 1 ns (LOR-200) the measured value has to be modified accordingly. For a pulse width of 2 ns 3 dB have to be subtracted from this value; for a pulse-width of 10 ns, 10 dB have to be subtracted; for 100 ns subtract 20 dB, and so on.

Since this coefficient remains constant, it is recommended to save the measured value within the User Setting for later usage

This procedure assumes that the fiber inside the OTDR and the FUT are of the same type. Contact Luciol if different types of fiber are to be tested.

5.2 Example measurement sessions

This section describes in detail some typical applications of the LOR-200/220 and gives a step by step description of the corresponding measurement sessions.

5.2.1 Fiber loss measurement

In this example session the total loss and the loss/km of a fiber under test (10 km) is measured with a LOR-200.

Setup:

- Connect the FUT to the OTDR
- Go to the ***Settings*** tab and enter the following parameters
    - Select the emitter
    - Set the distance range to 20 km
    - Set the pulse-width to 1000 ns
    - Enter the refractive index of your fiber according to the manufacturer
    - Set the distance unit to km
    - Set Start to 0 ; set End to 12
    - Set Average to 2
    - Set Resolution to Auto (250 ns)
- If needed, go to the ***ID*** tab and enter the fiber identification parameters
- Start the measurement and wait until the scan has finished

Select LOSS LMS from the ANALYSIS menu and set cursor A to the beginning of the FUT and cursor B to the end of the FUT. The result of the measurement is shown in Figure 17.

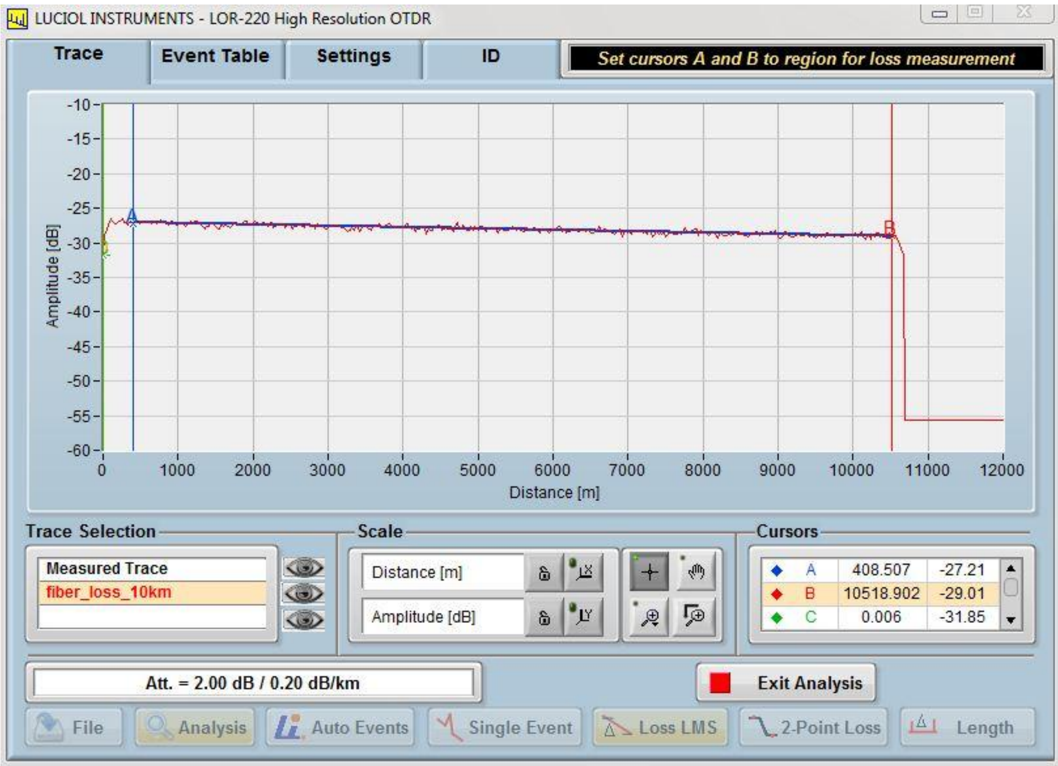


Figure 17: A typical fiber loss measurement

The result of the measurement is shown in the measurement bar; here we find a total loss of 2 dB and a slope of 0.2 dB/km. Click EXIT ANALYSIS to make the next measurement.

5.2.2 Single event analysis - Insertion loss and reflectance

Due to the very high resolution and the short dead-zones the LOR-200/220 is capable of making insertion loss measurement on very short fiber samples. In this example session we show that even the insertion loss and the reflectance of the output connector of the instrument can be measured.

Setup:

- Connect the FUT to the OTDR
- Go to the ***Settings*** tab and enter the following parameters
  - Select the emitter
  - Set the distance range to 1.25 km
  - Set the pulse-width to 2 ns (LOR-200 only)
  - Enter the refractive index of your fiber according to the manufacturer
  - Enter the correct backscatter-coefficient of your fiber under test
  - Set the distance unit to meter
  - Set Start to -2 and End to 2
  - Set Average to 3 (depending on the precision required)
  - Set Resolution to Auto (0.5 ns)
  - Set the event detection thresholds if needed
- If needed, go to the ***ID*** tab and enter the fiber identification parameters
- Start the measurement and wait until the scan has finished

Select SINGLE EVENT from the ANALYSIS menu and set cursor A to the event location (The event location is set to the center of the peak for LOR-220 systems using a fixed pulsewidth of 1ns, for LOR-200 systems with variable pulsewidth the event location is the beginning of the event). Set the first two markers before the event and two markers after the event. Figure 18 illustrates the recorded OTDR trace together with the cursor and the markers set correctly for single event analysis. SLOPE OFF will do a horizontal fit between the marker positions. Use this setting for short fiber sections without losses, as in this example. For longer fiber sections or high loss fibers (e.g polymer fibers) selecting SLOPE ON is recommended.

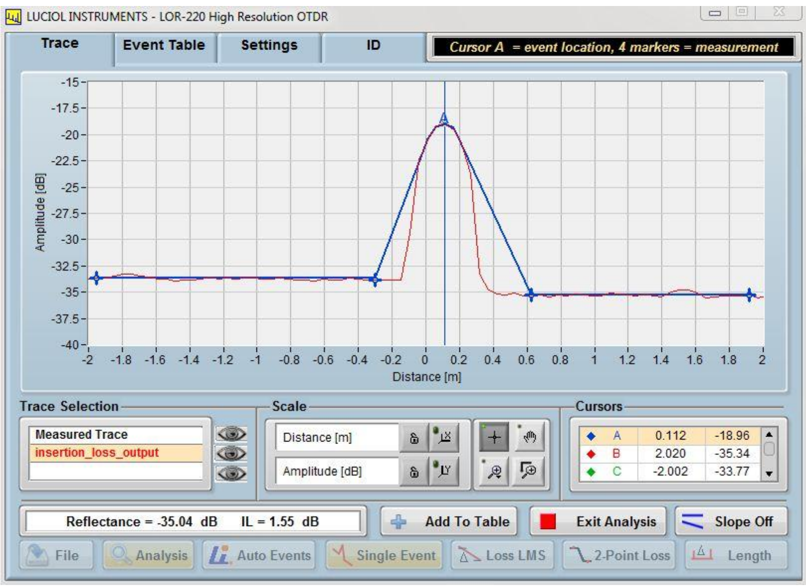


Figure 18: Reflectance and insertion loss measurement of the OTDR output-connector

The result of the measurement is shown in the measurement bar; here we find a reflectance of -35.04 dB and an insertion loss of 1.55 dB. This result is added to the event table when clicking the ADD TO TABLE button. Click EXIT ANALYSIS to make the next measurement.

Note that a connector with high insertion loss has been used in this example for illustration. The typical insertion loss at the output connector is < 0.4 dB.

5.2.3 2-point loss measurement

The 2-point loss measurement function allows a fast test of the loss between two points on the OTDR trace. A typical application is the measurement of the total loss of a fiber assembly. An example measurement is shown in Figure 19.

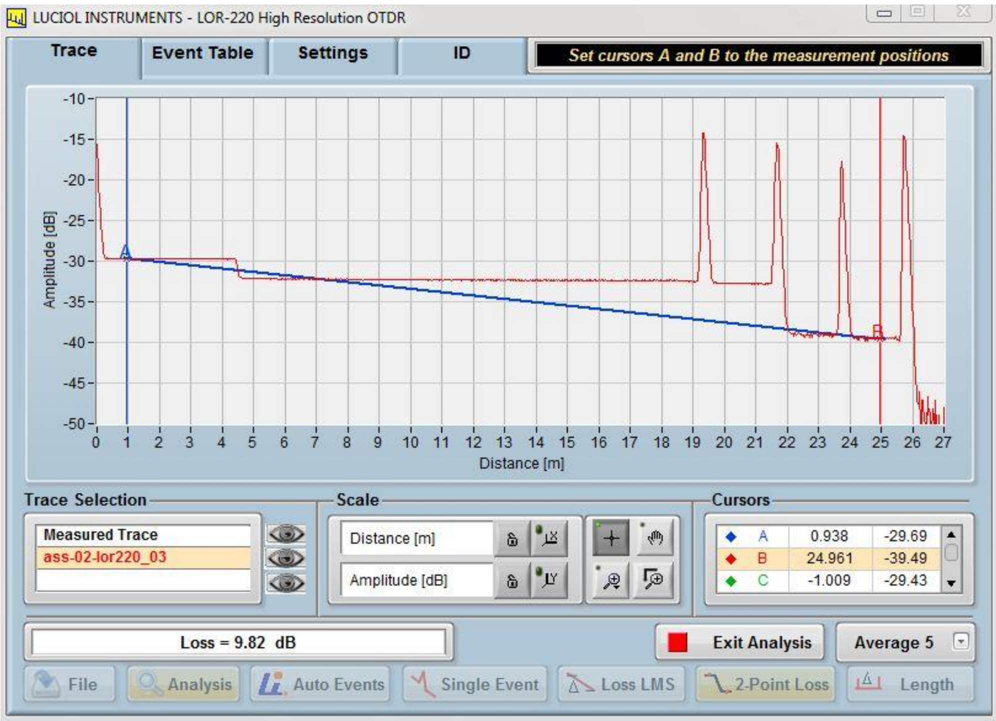


Figure 19: Making a 2-point loss measurement

Record a trace of the fiber assembly under test. Select 2-POINT LOSS from the ANALYSIS menu and set cursors A and B to the points on the trace where the loss is to be measured. Use the AVERAGE control to select the region around cursors A and B which will be used to calculate the loss. The region used for calculating the average value around the cursors will be indicated by a thick blue line.

5.2.4 Length measurements

Due to the very high resolution, the LOR-200/220 enables precise length measurements on optical fibers. A semi-automatic software tool is supplied which simplifies this task. The positions of two user selected peaks are precisely localized by an automatic quadratic peak fitting algorithm and their distance is calculated automatically.

In this example session, the length of a 5 m fiber patchcord connected to the OTDR is measured.

Setup:

- Connect the FUT to the OTDR
- Go to the ***Settings*** tab and enter the following parameters
    - Select the emitter
    - Set the distance range to 1.25 km
    - Set the pulse-width to 2 ns (LOR-200 only)
    - Enter the refractive index of your fiber according to the manufacturer

- Set the distance unit to meter
- Set Start to -1 and End to 6
- Set Average to 3
- Set Resolution to 0.25
- If needed, go to the ***ID*** tab and enter the fiber identification parameters
- Start the measurement and wait until the scan has finished

Select LENGTH from the ANALYSIS menu and set cursor A close to the center of the first peak and cursor B close to the center of the second peak (the fit will automatically be centered to the peak). Click ADD TO LIST if you wish to add the result to the list containing the length measurement results (this list will also be saved when saving the OTDR trace). Click SHOW LIST to open a list view of all length measurement results. Select EXIT ANALYSIS to close the length analysis session. Figure 20 shows the recorded OTDR trace together with the automatically created quadratic fits and the measured length. In this example we find a fiber length of 5.172 m. The precision of this measurement is typically better than 1 cm.

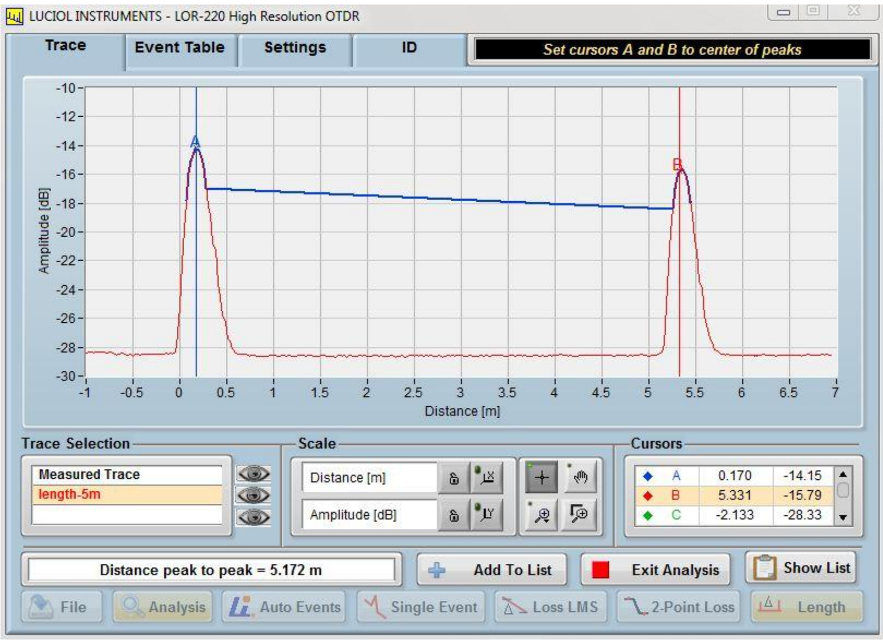


Figure 20: Measuring the fiber length

5.2.5 Testing a passive optical network (PON)

There are several applications where this type of high-resolution and high-sensitivity photon-counting OTDR can outperform conventional OTDRs. All conditions, where a high spatial resolution measurement on low backscattered signals is required are typical fields of application. One example is a passive optical network (PON). Here, the fiber spans are relatively short, and due the 1x8 or 1x32 distribution couplers the losses are high. Also, a high spatial resolution is required to resolve closely spaced reflective events. In this example session, we record OTDR-traces from the configuration shown in Figure 21.

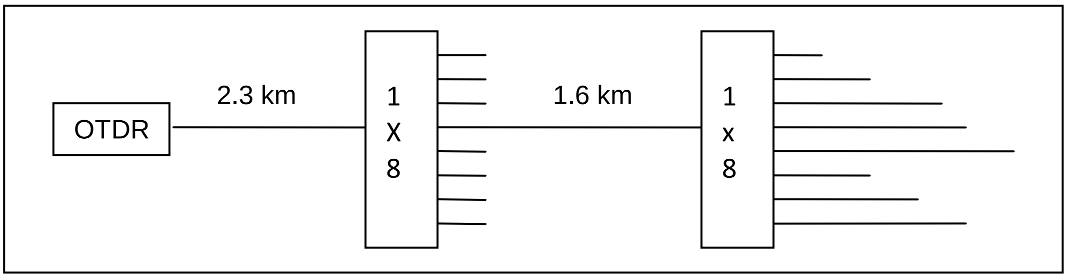


Figure 21: Fiber optical PON configuration

The OTDR is connected to a 2.3 km long fiber spool followed by a 1x8 optical coupler. One output fiber of the coupler is connected to a 1.6 km long fiber followed by a second 1x8 coupler. The 8 output fibers of the second coupler are cut to different lengths. This way, optical network terminals at different location are simulated.

Setup:

- Connect the FUT to the OTDR
- Go to the ***Settings*** tab and enter the following parameters
  - Select the emitter
  - Set the distance range to 5 km
  - Set the pulse-width to 300 ns
  - Enter the refractive index of your fiber according to the manufacturer
  - Set the distance unit to meter
  - Set Start to 0
  - Set End to 4000
  - Set Average to 5
  - Set Resolution to Auto (75 ns)
- If needed, go to the ***ID*** tab and enter the fiber identification parameters
- Start the measurement and wait until the scan has finished

This first measurement gives an overview trace of the entire PON as illustrated in Figure 22.

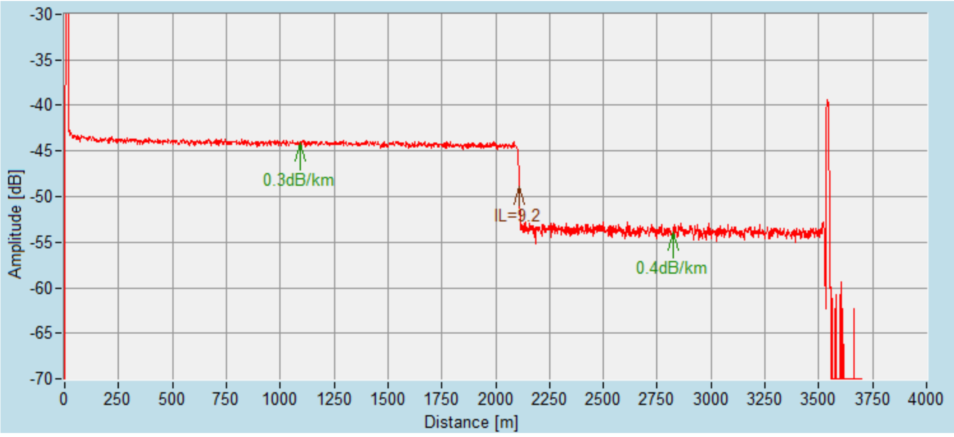


Figure 22: PON OTDR trace 300 ns pulsewidth

Fiber loss measurements and an insertion loss test of the first coupler have been done as described in sections 5.2.1 and 5.2.2.

The resolution of this first measurement is insufficient to resolve the location of the optical network terminals simulated by the open fiber ends. Therefore a second measurement is performed on the PON:

Setup:

- Go to the ***Settings*** tab and change the following parameters
  - Set the pulse-width to 2 ns
  - Set Start to 3530 (before the first terminal)
  - Set End to 3540 (after the last terminal)
  - Resolution will auto-set to (0.5 ns)
- If needed, go to the ***ID*** tab and enter the fiber identification parameters
- Start the measurement and wait until the scan has finished

This second measurement is a high resolution trace showing only the 8 terminal reflections as illustrated in Figure 23.

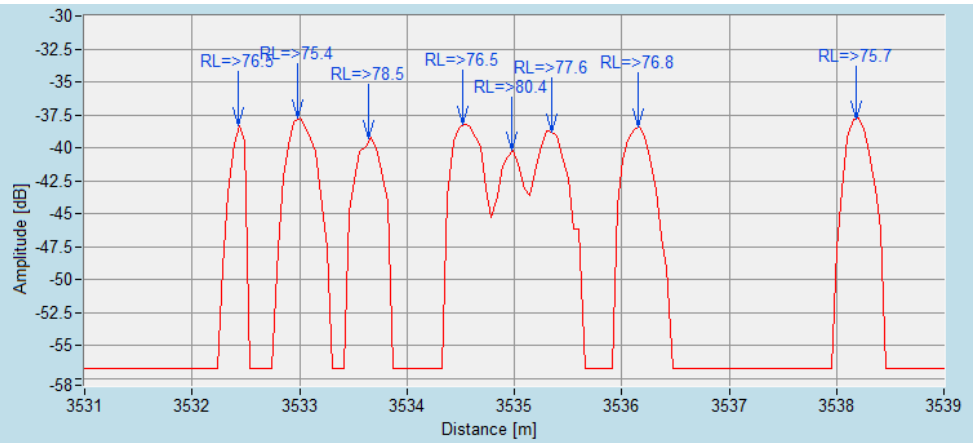


Figure 23: PON trace - high resolution measurement at the terminal locations

The high spatial resolution and the minimal dead-zone of the instrument mow make all 8 reflective events visible. Adjacent reflections spaced by only 20 cm can be resolved.

5.2.6 Comparing traces

This example session demonstrates the use of the LOR-200/220 for trace comparison. The measured trace is compared with one or more previously stored traces to monitor changes in fiber losses or peak locations.

The first example monitors the length of an optical fiber of 7.8 km length as the ambient temperature varies.

Setup:

- Connect the FUT to the OTDR
- Go to the ***Settings*** tab and enter the following parameters
  - Select the emitter
  - Set the distance range to 10 km
  - Set the pulse-width to 2 ns (LOR-200 only)
  - Enter the refractive index of your fiber according to the manufacturer
  - Set the distance unit to meter
  - Set Start to 7815 (a few meters before the end reflection)
  - Set End to 7818 (a few meters after the end reflection)
  - Set Average to 5
- Set Resolution to 0.25 ns (highest)
- If needed, go to the ***ID*** tab and enter the fiber identification parameters
- Start the measurement and wait until the scan has finished
- Save the result of this first measurement
- Repeat the measurement when the ambient temperature has changed and save the results again
- Load the trace(s) of the previous measurement(s) and start the measurement which should be compared with the stored reference trace(s).

Figure 24 shows the result of this fiber length measurement at three different temperatures. The high spatial resolution allows the detection of a fiber length variation in the cm range.

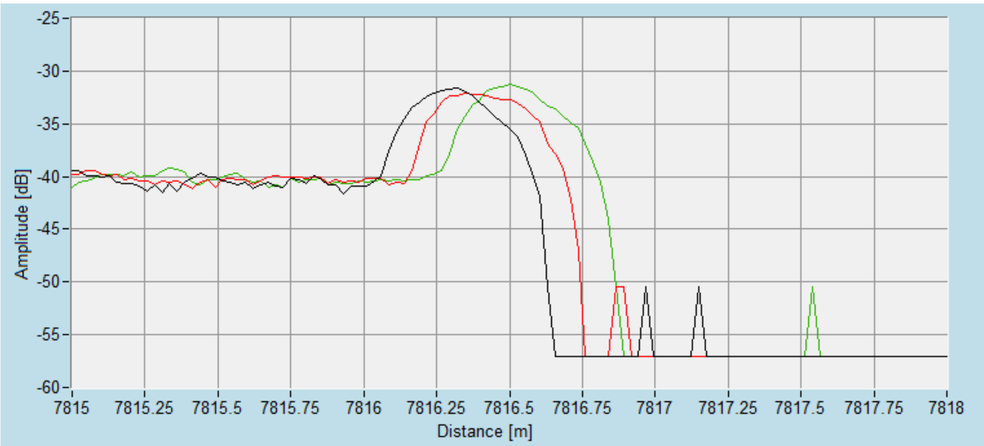


Figure 24: Comparing traces - Peak positions

> **Note:** When comparing peak positions, the peaks should have the same amplitude for precise localization.

The second example monitors an insertion loss variation. The current insertion loss is compared with two previously stored results. Refer also to section 5.2.2 for insertion loss measurements. The fiber under test is a 20 m patchcord with a bend induced loss at about 17 m.

Setup:

- Connect the FUT to the OTDR
- Go to the ***Settings*** tab and enter the following parameters
  - Select the emitter
  - Set the distance range to 1.25 km
  - Set the pulse-width to 2 ns (LOR-200 only)
  - Enter the refractive index of your fiber according to the manufacturer
  - Set the distance unit to meter
  - Set Start to 16
  - Set End to 19
  - Set Average to 5
  - Set Resolution to Auto (0.5 ns)
- If needed, go to the ***ID*** tab and enter the fiber identification parameters
- Start the measurement and wait until the scan has finished
- Save the result of this first measurement as the first reference trace
- Make a second measurement (e.g. at the maximum insertion loss allowed) and save the results again
- Load the traces of the two reference measurement

The actual measurement can now be compared with the two reference traces. This type of test can serve to decide if the insertion loss of the FUT is within the range given by the two reference traces and to monitor long term loss fluctuations. A typical result is illustrated in Figure 25.

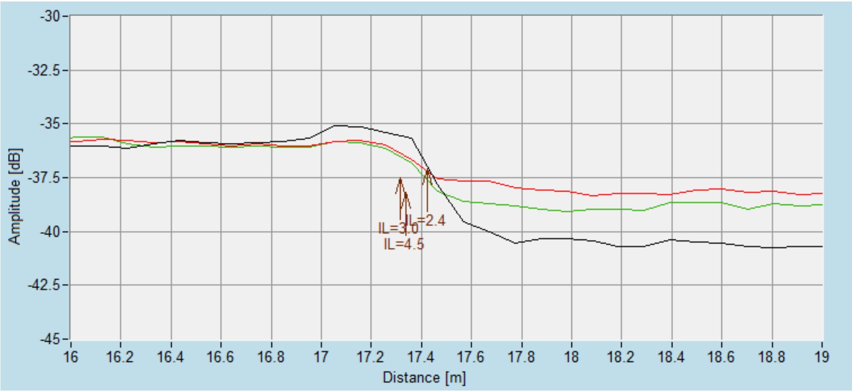
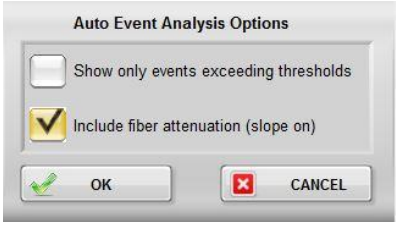


Figure 25: Comparing traces - Insertion loss

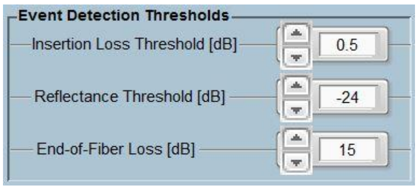
5.2.7 Auto event detection and the event table



The recorded traces can be automatically analyzed using the AUTO EVENTS function from the ANALYSIS menu. The pop-up window shown on the right will open to select the analysis options.

For correct reflectance measurements the Backscatter Coefficient needs to be set according to the fiber under test. Also the "End of Fiber Loss" value should correspond to the recorded trace. The user can define insertion loss and reflectance thresholds. Events exceeding these thresholds will be marked red while other events will be marked grey. When checking the option "Show only events exceeding thresholds" only those events (red) will be shown and added to the event table. Checking the option "Include fiber attenuation" will enable fiber slope measurements and add the results to the event table. This option is recommended if there are long fiber sections between the events with fiber losses exceeding 0.1 dB. For short sections the measurement is simplified by disabling this options.

Figure 26 is an example trace with the corresponding event table after using the auto-events function. The selected ***Auto Event Settings*** are shown on the right.



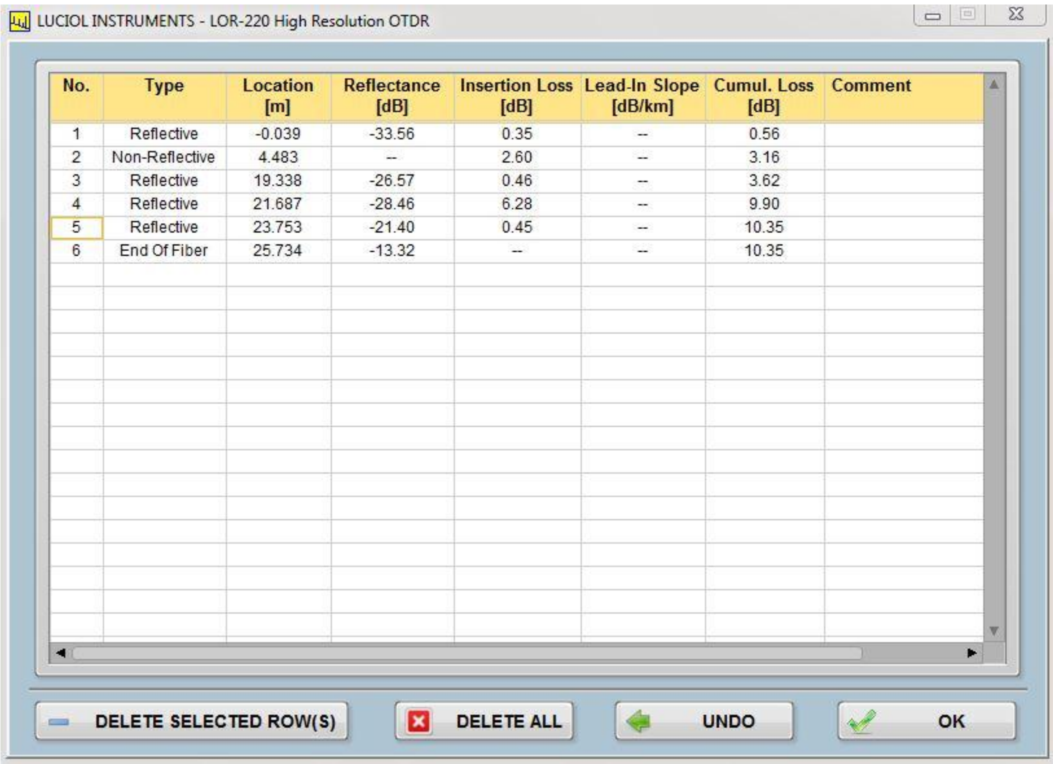
No.	Type	Location [m]	Reflectance [dB]	Insertion Loss [dB]	Slope [dB/km]	Cumul. Loss [dB]	Comment
1	Reflective	-0.039	-33.56	0.35		0.56	
	Section 4.52m			0.00	--	0.56	
2	Non-Reflective	4.483	--	2.60		3.16	
	Section 14.86m			0.00	--	3.16	
3	Reflective	19.338	-26.57	0.46		3.62	
	Section 2.35m			0.00	--	3.62	
4	Reflective	21.687	-28.46	6.28		9.90	
	Section 2.07m			0.00	--	9.90	
5	Reflective	23.753	-21.40	0.45		10.35	
	Section 1.98m			--	--	--	
6	End Of Fiber	25.734	-13.32	--		10.35	

Figure 26: Using the auto-events function

When using the AUTO EVENTS function all found events are automatically added to the event table.

> **Note:** In order to work correctly, the AUTO-EVENTS function requires at least 1m of a fiber section before the first event. If you want to include the output connector of the OTDR to the event list, start the measurement at < -1m (as in the example of Figure 26). Otherwise, if the device under test is connected with a patch-cord of e.g. 3m length to the OTDR start the measurement at 1 or 2m.

It is possible to modify the automatically created table, to delete some events, or to add comments to events. Click the EDIT EVENTS in the ***Event Table*** tab. This will open an event table editor window as shown in Figure 27.



No.	Type	Location [m]	Reflectance [dB]	Insertion Loss [dB]	Lead-In Slope [dB/km]	Cumul. Loss [dB]	Comment
1	Reflective	-0.039	-33.56	0.35	--	0.56	
2	Non-Reflective	4.483	--	2.60	--	3.16	
3	Reflective	19.338	-26.57	0.46	--	3.62	
4	Reflective	21.687	-28.46	6.28	--	9.90	
5	Reflective	23.753	-21.40	0.45	--	10.35	
6	End Of Fiber	25.734	-13.32	--	--	10.35	

Figure 27: The event table editor

Select a row and click DELETE SELECTED ROW(S) to remove events from the table. Click DELETE ALL to empty the entire table. You can also add comments or do other modifications to the event table. Click OK to return to the main window after editing.

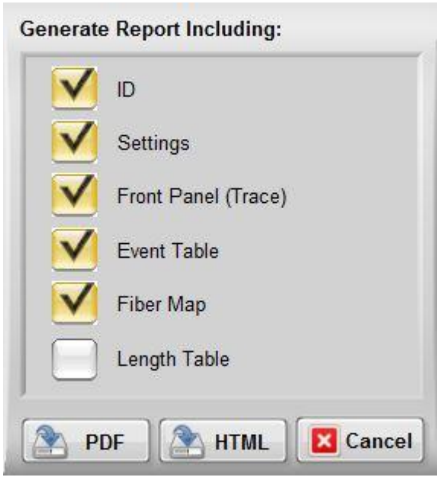
> **Note:** The auto-event function may not find the correct fiber loss on too short fibers. Delete unwanted entries using the event table editor. When reflective events are too close to each other not all events can be detected by the auto-events function. Use the manual events functions to add undetected events to the table.

A simplified graphical representation of the event table is obtained by clicking SHOW MAP in the ***Event Table*** tab (see Figure 10).

6 Creating Reports, Printing Results

With the LOR200/220 software you can automatically create a detailed report of your measurement results.

Select FILE – REPORT in the TRACE tab. This will open the following list with the report options:



First select the items you want to include in your report.

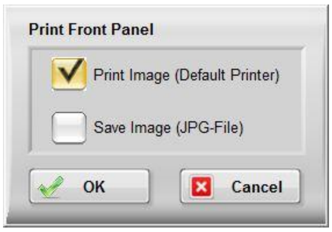
Next select the report format by clicking on the PDF or the HTML button. A file dialog will open to save the report according to the user selections.

Note that if the HTML format is used, several files will be created (the HTML-file and some image files).

Hint:

If you want to save or print only the visible part of the front panel, click on the status indicator when showing READY.

This will open the following dialog.



7 Visual Fault Locator (Option)

A visual fault locator (VFL) is available as an option. The VFL option provides a blinking intensive red laser source at the OTDR output. The VFL is used to visually detect fiber breaks. A second application is the identification of the fiber connected to the OTDR in a cable containing several fibers.

The VFL is activated by clicking the VFL button. Click the VFL button again to go back to normal OTDR operation.

Figure 28: The VFL option

8 Optical Power Meter (Option)

An optical power meter (OPM) is available as an option. A double-click on the OPM icon on the desktop will open the OPM panel as shown in Figure 29.

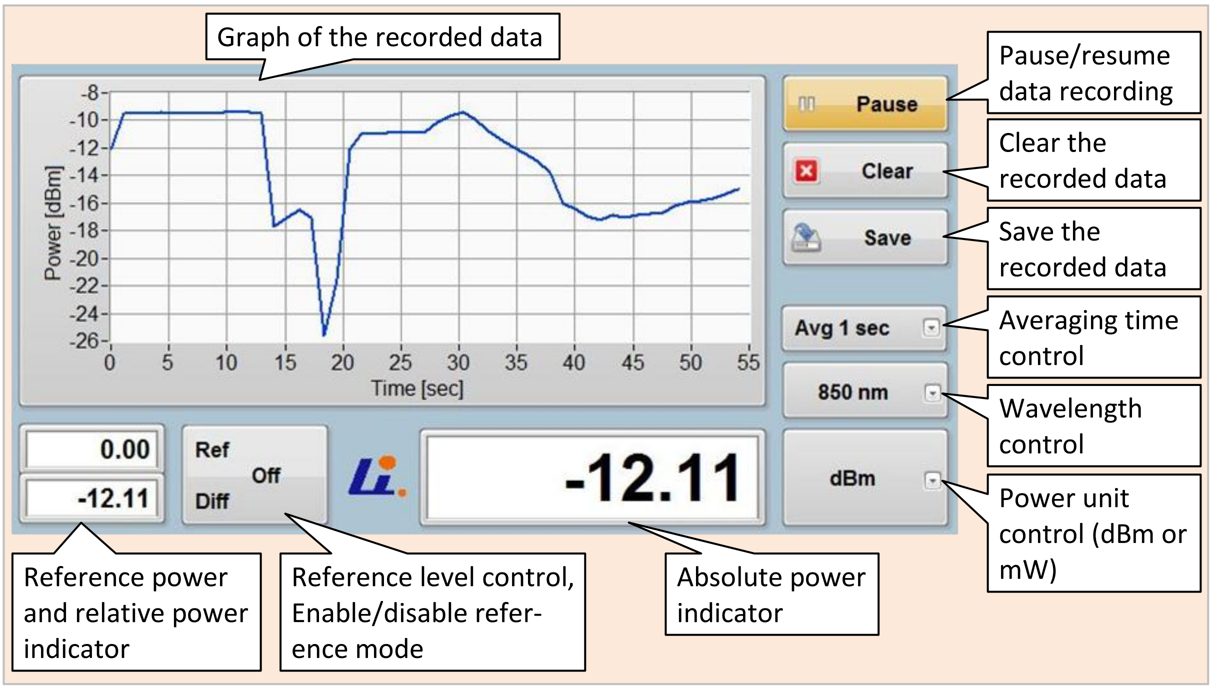


Figure 29: The user-interface of the optical power meter.

The OPM will start data acquisition after start-up. Data recording can be paused or resumed by clicking the PAUSE button. The CLEAR button will clear all recorded data.

First set the wavelength control according to the wavelength of the light source. Please note that a stabilized cw-source is required for precise measurements. Next set the power unit control to dBm or mW. Changing the wavelength or the power unit will clear the previously recorded trace. For most applications the averaging time control can be left at it default value of 1 seconds, the value can be changed by clicking the control.

Relative power measurements are enabled by clicking the reference level control. The current power level will be used as reference level and the relative power will be indicated by the reference level indicator and the graph. Click the reference level control again to go back to the absolute power mode.

The recorded data is saved by clicking the SAVE button. This opens a dialog where you can select the name and the path of the file to save. The saved data is in a standard text (ASCII) format. It can easily be exported to other applications.

The following is an example of a saved data-file:

```
Luciol Instruments SA
OPM Text File Format Version 1.0
[DateTime]
12/16/2011
11:57 AM
[-]
[Wavelength]
1310 nm
[-]
[Power Unit]
dBm
[-]
[Reference Level]
-46.760000000
[-]
[DataPoints: Time [sec] - Absolute Power - Relative Power]
0.000000000    -46.980000000   -0.220000000
1.080000000    -46.740000000   0.020000000
2.160000000    -47.370000000   -0.610000000
3.240000000    -47.310000000   -0.550000000
4.320000000    -47.680000000   -0.920000000
5.400000000    -47.720000000   -0.960000000
6.480000000    -47.180000000   -0.420000000
7.560000000    -46.730000000   0.030000000
8.640000000    -46.740000000   0.020000000
9.720000000    -46.740000000   0.020000000
10.800000000   -46.740000000   0.020000000
[-]
```

The technical specifications of the optical power meter can be found in section A.4.

9 Wavelength tunable OTDR

This section applies to wavelength tunable OTDRs only.

9.1 Setting the wavelength

When starting the OTDR the main OTDR application and the wavelength control application are launched automatically. If one of the applications is not running or has been closed double-click on the corresponding desktop short-cut.

The wavelength control in the main OTDR application is disabled; it will show the center wavelength of the tuning range. The operating wavelength is set using the *LOR-200_wavelength* application as shown in the following:

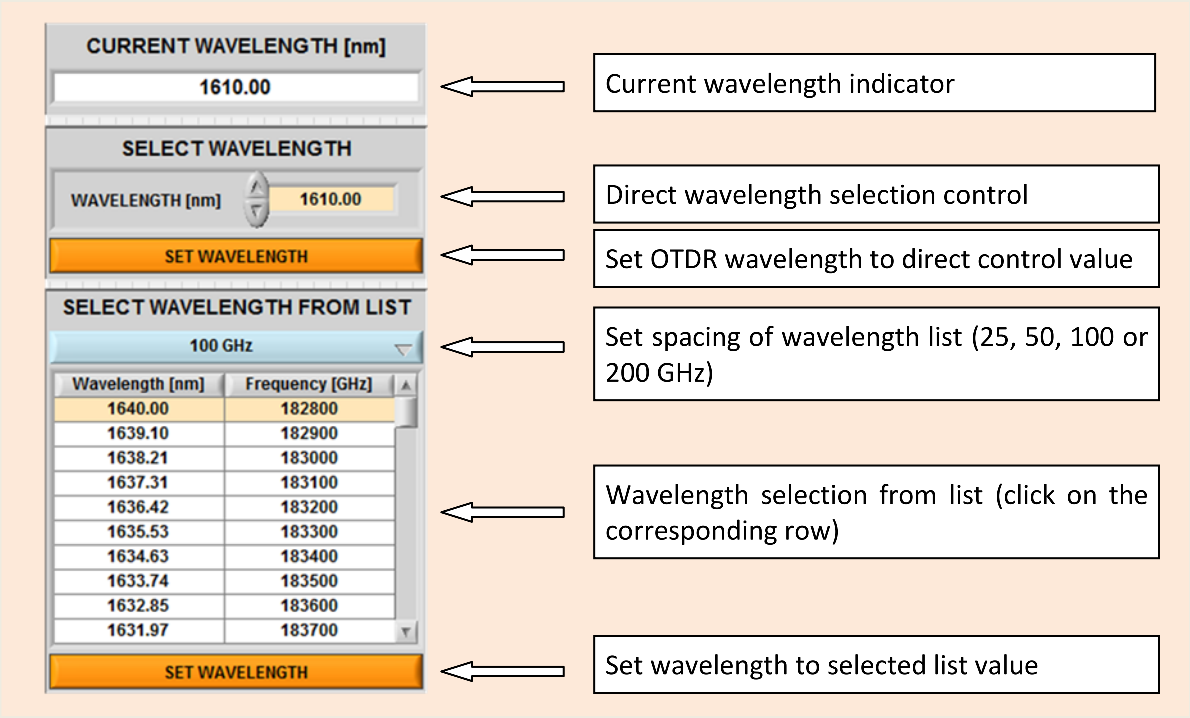


Figure 30: Using the wavelength control application

When first starting the software an initialization procedure is started. During this time the wavelength indicator is blinking. When finished, the wavelength will be set to the center of the tuning range. This process will take about 20 seconds.

There are two options to change the operating wavelength of the OTDR: First the wavelength can be set directly using the upper wavelength control. After selecting the wavelength click the upper ***SET WAVELENGTH*** button to execute the wavelength change.

The second option is to select the operating wavelength from the wavelength list by clicking on the corresponding row (scroll down for more wavelengths). After setting the wavelength click the lower ***SET WAVELENGTH*** button to execute the wavelength change. The spacing of the wavelength list can be set to 25, 50, 100, or 200 GHz.

Appendices

A. Specifications

A.1. General specifications

Operating system: .... Windows® Embedded POSReady 7

Processor: .... AMD G T40E, 2x 1 GHz

RAM: .... DDR3, 2 GB

Storage:.. SSD, 60 GB

Display: .... Touchscreen TFT 10.4”; 800x600 pixels

Interfaces:.. 1x Ethernet RG45; 2x USB Type 2; 1x VGA; 1x Serial port

DC input power rating: .... 15V/3.2 A

External AC adaptor:................................ 100 to 240 VAC, 50/60 Hz

Battery: .... Li Ion, 6.6 Ah

Battery operating time: .... 5 h

Battery charging time: .... 3.5 h

Size:... 320 x 240 x 90 mm

Weight: .... 3.1 kg

Operating temperature: .... 0˚ to +40˚C (32° to 104° F)

Storage temperature: .... -20˚ to +60˚C (-4° to 140° F)

Humidity: .... 0% to 90% non-condensing

A.2. Optical specifications LOR-200

Standard wavelengths[§]:............................1310 nm; 1490 nm; 1550 nm; 1625 nm[**]

Fiber type:..Single-mode (9/125), multi-mode (62.5/125, 50/125)

Optical connector:...................................Universal, APC or PC type

Optical pulse width:.................................2ns, 5ns, 10ns, 30ns, 100ns, 300ns, 1μs

Measurement range:................................1.25, 2.5, 5, 10, 20, 40, 80, 160km

Distance units:...Kilometer, meter, feet, miles, time (ns)

Sampling resolution:................................Any multiple of 2.5 cm (250ps)

Total number of samples/trace................Measurement range/sample spacing

Dynamic range:..30 dB / 28 dB (1625 nm)[††]

Reflectance dynamic range:......................98 dB (any pulsewidth; -10 dB to -108 dB)

Sensitivity ....-110 dB

Event dead zone[‡‡]:....................................20 cm

Attenuation dead zone[‡‡]:..........................50 cm

Distance accuracy:...................................$\pm$ (10 mm + [fiber length]$\cdot 5\cdot 10^{-5}$)

Reflectance accuracy:...............................± 1dB

[§] Others available on request
[**] Optional with Raman filter for active PON monitoring
[††] For 1 μs pulsewidth, 15 dB for 2 ns pulsewidth; S/N=1
[‡‡] For a pulsewidth of 2 ns and an ORL of 45 dB

A.3. Optical specifications LOR-220

Standard wavelengths[§§]:............................670 nm, 850 nm

Fiber type:..Multi-mode (62.5/125, 50/125), single-mode

Optical connector: ....Universal, APC or PC type

Optical pulse width:.................................1 ns

Measurement range:................................1.25, 2.5, 5, 10, 20, 40, 80, 160km

Distance units: ....Kilometer, meter, feet, miles, time (ns)

Sampling resolution:.................................Any multiple of 2.5 cm (250ps)

Total number of samples/trace ....Measurement range/sample spacing

Dynamic range:..>20 dB[***]

Reflectance dynamic range: ....98 dB (-10 dB to -108 dB)

Sensitivity...-110 dB

Event dead zone[†††]: ....10 cm

Attenuation dead zone[‡‡]: ....40 cm

Distance accuracy: ....± (10 mm + [fiber length]$\cdot 5 \cdot 10^{-5}$)

Reflectance accuracy: ....± 1dB

A.4. Specifications Optical Power Meter (Option)

Center wavelengths:................................850, 1310, 1550, and 1610 nm

Optical power range:................................-55 dBm … +3 dBm , (-50 dBm … +8 dBm at 850 nm)

Linearity:..< ± 0.05 dB (between -45 and 0 dBm)

Absolute power uncertainty:.....................< ±0.2 dB

Resolution:...0.01 dB

Fiber compatibility:..................................All (core ≤ 0.5 mm)

Receptor diameter:...................................1 mm

[§§] Others available on request
[***] For 1 ns pulsewidth; S/N=1
[†††] For a pulsewidth of 1 ns and an ORL of 45 dB

B. Warranty and maintenance policy

B.1. Limited warranty

Luciol Instruments warrants the Luciol Instruments hardware Product against defects in materials and workmanship and that the Product will conform to the current specifications under normal use and service. Luciol warrants that Luciol owned standard Software substantially conforms to Specifications.

The warranty period for the product can be found on Invoice and Delivery note documents related to the purchase of the product.

The warranty provided herein shall extend to any product which has proved defective and has failed through normal use, but excludes and does not cover any product or parts thereof which has been accidentally damaged, disassembled, modified, misused, used in applications which exceed the product specifications or ratings, neglected, improperly installed or otherwise abused or used in hazardous activities. In particular, optical connectors and batteries are excluded from the warranty.

The customer shall contact Luciol Instruments SA to obtain an authorization before shipping back a product to the manufacturer for service. The customer will be provided with a RMA number and instructions for shipment.

For complete warranty conditions, please refer to the Luciol Instruments current “Terms and conditions of sale” document, available upon request.

Note: Customer service over the phone or e-mail is free of charge

Note: Failure to obtain a RMA before shipment, and/or instructions to follow may results in delays and may void the warranty.

B.2. Extended warranty options

The Customer may choose to purchase an extended warranty option, offering an extension period of the initial warranty, under the same conditions and limitations. Please contact Luciol Instruments for pricing information.

B.3. Installation and training

Once the equipment has been delivered to the Customer, Luciol Instruments can provide an installation and training course. Please contact Luciol Instruments for pricing information. Customer Service contact informations can be found on www.luciol.com.

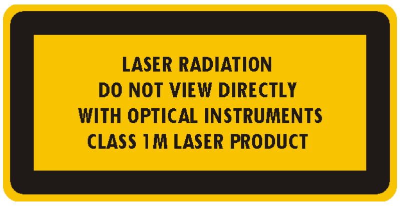
C. Safety

C.1. Laser safety

The instrument complies with the optical safety standards in class 1M of the IEC 60825-1 (2001).

Warning: Viewing the laser output with certain optical instruments (for example, eye loupes, magnifiers and microscopes) within a distance of 100 mm may pose an eye hazard.

Depending on the operation wavelength(s), one of the following pair of labels is affixed to the instrument:



For detailed wavelength information see the label attached to the instrument or refer to the test sheet of your instrument.

C.2. External power supply

Always use the external power supply supplied with the instrument. Use of any other supply may void the warranty, and may lead to damage to the equipment or fire.

C.3. Electric cables

To prevent electric shock, never use damaged cables or plugs

Never bend or twist the electric cable to unplug the unit. Do not place heavy or sharp items on the cable. Always pull on the plug itself to unplug the unit.

Do not attempt to dismantle or repair the external power supply. Contact us for replacement.

C.4. Safety instructions

To ensure correct functionning of the instrument, do not block the ventilation holes on each side of the instrument.

D. Complience symbols

Management of WEEE (waste electrical and electronic equipment)

The symbol on the product or on its packaging indicates that this product may not be treated as regular household waste. By ensuring this product is disposed of correctly, you will help protect the environment. For more detailed information about the recycling of this product, please contact your local authority, your household waste disposal service or contact your local Luciol Instruments distributer.

CE

The instrument complies with EN61326: 2002 (Class A), EN61010-1: 2001, EN 60825-1

E. Battery declaration

Battery type used in LOR OTDRs: Li-Ion, 6 cells, < 100Wh, in compliance of section II or PI 967

For shipping:

· Shipper's declaration is not required

· Equipment must be in strong outer packaging

· Pack must display an IATA lithium battery label as below:

· The following statement must be included on the air waybill (if an air waybill is used): "Lithium ion battery in compliance with Section II of PI967"

· No dangerous goods declaration to be done.

For Air transportation within passenger baggage:

Batteries for the LOR OTDRs meet the requirements of the UN Manual of Tests and Criteria, Part III, subsection 38.3 and therefore the LOR OTDR can be carried in a carry-on baggage or checked baggage with no restriction.

(Passenger must take measures to prevent unintentional activation)

All spare batteries for the LOR must be individually packed and protected to prevent short-circuit.

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