LUCIOL INSTRUMENTS

ν-OTDR

High Resolution OTDR

User's Manual

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1 Introduction

The ν-OTDR is a high resolution OTDR manufactured by Luciol Instruments. It is specially designed for short-range analysis of optical networks. Typical examples are for Local Area Networks, buildings, cars and planes, fiber optical devices and sensors, and for plastic optical fibers, where optical spans are typically in the tens to hundreds of meters range. The instrument can also be used as a zoom, to analyze short sections of a long fiber (up to 40 km), with the same high resolution. Standard types of OTDRs, with a resolution in the meter range and above are not suitable for this type of applications. The photon-counting technology allows detection systems, which are at the same time fast, so as to detect the very short optical pulses necessary for high resolution, and also very sensitive, to match the very weak light levels, generally associated with the high resolution (e.g. the Rayleigh Back Scattering in a SMF at 1550 nm is typically -80 dB for a cm-range resolution). It is this dual advantage, speed and sensitivity, which provides the ν-OTDR with its unique properties.

The ν-OTDR will allow you to characterize optical spans of several hundred meters, with a very high spatial resolution. 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 (e.g. bends or pressure points). You can see losses and backreflections from connectors or optical components.

The ν-OTDR is a simple and easy-to-use instrument, with user-friendly GUI software. Although we have tried to provide versatile software, which should suit your particular needs, we also acknowledge that you may require some particular features, which may not be included with the standard package. Therefore, we are ready to examine with you any special requirement for the interface.

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

2 Quick Guide

This quick guide presents a simple step-by-step approach to optical fiber testing with ν-OTDR. You should read it if you need to learn how to operate the instrument quickly. You may then read the other sections as needed.

2.1 Operating instructions for ν-OTDR

1) If the unit comes without a computer, use the instructions in the README file on the CD-ROM included with the unit to install all necessary software on your computer. Once this is done, the computer should contain the USB driver for the system and the necessary programs for running the unit.

2) Connect ν-OTDR into mains and switch it on, with the switch placed on the rear panel of the instrument.

3) Connect the ν-OTDR to the computer via the USB port, located on the front panel of the instrument.

4) Go to the Windows® START menu, and click the OTDR icon. You may also double-click the OTDR shortcut on the desktop. The photon-counting OTDR main-screen should now appear.

5) If required, check the SETTINGS tabs (especially, the refractive index and the x- and y-scales). The defaults settings should be satisfactory for an initial test of a fiber. You may also select the wavelength (for multi-wavelengths systems) in the ADVANCED SETTINGS tab.

6) Connect the Fiber Under Test (FUT) to the ν-OTDR, and click on the start button (labeled with the OTDR status, currently on OFF) to start the measurement. The OTDR status turns to ON, and the LED displayed on the button becomes green. After a few seconds, the traces appear on the screen. The integration goes on, until the same button is pressed again. In general, less than one minute is sufficient to obtain a good measurement.

At the end of the measurement, a window opens, asking whether or not to save the measurement. Click YES or NO as required and follow the instructions. By default, the file is saved with the extension *.luc. The saved file is a text file, which can later be opened and processed with the OTDR software, using the LOAD FILE command in the FILE menu.

2.2 Notes

2.2.1 Help function

In order to use the HELP function, open the help menu on the upper task bar, then single-click the SHOW CONTEXT HELP feature. You may also press 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.

2.2.2 Preparation for measurement

Due to the high sensitivity of the photon-counting detection, care has to be taken to avoid any stray light entering the measured fiber. Any open end should be covered, and the fiber should have an opaque jacket[†].

2.2.3 Loading saved data - Examples

Saved files can later be opened again with the program. Start the program; go to the FILE MENU and click LOAD DATA1 or LOAD DATA2. Select a file with the previous data. This data can be processed with the software, and printed with the PRINT WINDOW command. You can load up to two previously saved files.

The CD-ROM with the software contains example data files, which can be examined.

[†] This is not necessary for SMFs.

3 The Hardware

3.1 Description

The ν-OTDR is shipped with the following standard accessories:

- 1 external power adapter (100-240 VAC, 50-60Hz)
- 1 USB cable, for the connection between the OTDR and a computer
- 1 short fiber with matching connector, for testing the unit
- 1 CD-ROM with all necessary software, installation procedures and a **.pdf** version of this manual

Note that there exist several versions of the OTDR, with different fiber types. The type of fiber used in your instrument can be found by clicking INSTRUMENT INFO in the HELP menu. For better results, the OTDR should be used to measure similar types of fibers, although some mismatch is possible (e.g. a 50μ multimode fiber would be compatible with a 60μ one, with slightly higher connection losses). Different types of fibers can be provided upon request (contact Luciol Instruments for details). The type of connector on the OTDR has to be specified upon ordering. We will provide any major type of connector required.

3.2 Principle of a photon-counting OTDR

3.2.1 Limitations of standard OTDRs

All OTDRs are based on the same principle: a short pulse of light is sent towards the Fiber Under Test (FUT) through an optical coupler, and back reflected light is analyzed at a detector. In order to obtain a high resolution OTDR (< 10 cm), the optical pulses have to be very short (< 1 ns). The energy in such a pulse is also very weak, leading to weak light levels at the detector. Unfortunately, this brings about two conflicting demands: on the one hand, the detector needs to be very sensitive to deal with the weak light levels; on the other hand, the detector needs to be fast to be able to resolve the short pulses. Only photon-counting detection is able to resolve this conflict.

3.2.2 Photon-counting detection

It is well-known that light is made of photons. However, since the number of photons associated with a "normal" light level is very large, this fact can be safely ignored, and light can almost always be considered as a classical wave. At very low levels though, the quantum character of light (the fact that it is made of discrete particles: the photons), has to be taken into account. In the photon-counting OTDR, the backreflected light is attenuated, so that, for each pulse, which is sent towards the FUT, only one photon is coming back. In this case, we loose the deterministic, classical description, to go a probabilistic, quantum description. The photon may arrive at any time, with probability distribution given by the "classical" trace. The OTDR trace is now a histogram, built from the acquisition of a large number of pulses.

3.3 The ν-OTDR

The ν-OTDR is presented in Figure 1. It has to be plugged in the mains with the power adaptor. When the power is switched on, the yellow LED on the front panel is flashing for about one minute indicating the warm-up time of the instrument. The OTDR is ready when the LED continuously on. The short fiber patch cord is provided, to enable the testing of the unit, for example upon receiving the instrument.

Figure 1: The ν-OTDR

To operate the unit, the OTDR has to be connected to the USB interface of a computer. A USB cord is provided in the case for convenience. This cord can be plugged in or out at all time, even when the OTDR or the computer are on. However, we recommend not plugging or unplugging the cord when the program is running.

> **Important:** The power adaptor may become rather hot after prolonged use. This is normal, and does not affect the performance of the device.

3.3.1 Connectors

Figure 2 shows the external connectors of the ν-OTDR. The fiber optic connector is located on the left side of the front panel. Different types of fiber optic interfaces are available including interchangeable universal connectors. The Figure shows a universal connector with FC/APC interface. The USB connector is located on the right side of the front panel. Connect the instrument to an external PC via a standard USB cable (shipped with the instrument).

The power switch and the 15 V DC power supply input are located on the back panel of the instruments.

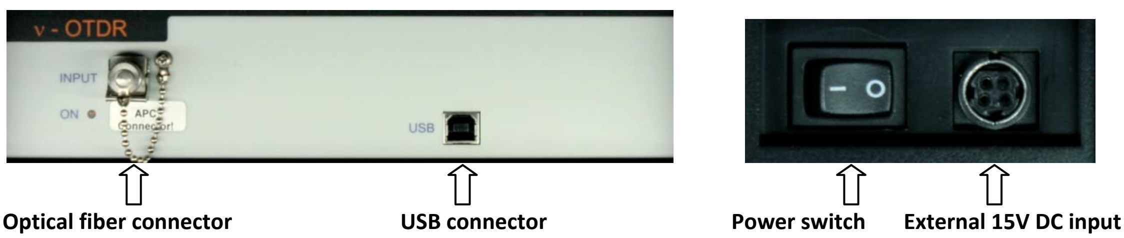


Figure 2: The front panel connectors (left) and the back panel connectors (right)

4 The Software

The ν-OTDR is a simple and easy-to-use instrument, with user-friendly GUI software written in Labview®. We provide 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. The software is regularly updated. Please contact Luciol Instrument for the latest version. This manual is based on the software version 5.0.

4.1 Installing the software

All units are provided with a CD-ROM, which contains all the necessary software. The installation procedure is outlined in the README file present in the CD-ROM. This file is reproduced here for convenience.

> This disk contains all the necessary software for installing and using the OTDR from Luciol Instruments. The software requires a computer with Windows 98 SE (Second Edition) or higher, including Windows Vista.
>
> Instruction for installation:
>
> 1. Click on Setup.exe and follow the instructions to install the v-OTDR software.
>
> 2. Switch the OTDR on and connect it to the computer via USB cable.
>
> 3. The computer will detect the new hardware, and will suggest installing it. Follow the instructions of the installation program. All the files required for installing the USB driver are in the "USB driver" directory of the CD-ROM. Note that Windows XP or Windows Vista users should ignore the warning, and can install the software safely.
>
> 4. Once the installation is completed, you may remove the disk
>
> 5. The directory "examples" contains examples of measurements, which may be loaded from the program, using "load data". The directory "application notes" contains application notes, which present various applications of the photon-counting OTDR.

Note that the installation program also installs the Labview® runtime engine, which is required to run the software.

4.2 First glance at the GUI

To start the program, go to the Windows® START menu and click the **OTDR** icon or double click on the OTDR shortcut on the desktop (if this was done). The measurement window shown in Figure 3 opens. You can then either load a previous measurement result, or start a new measurement.

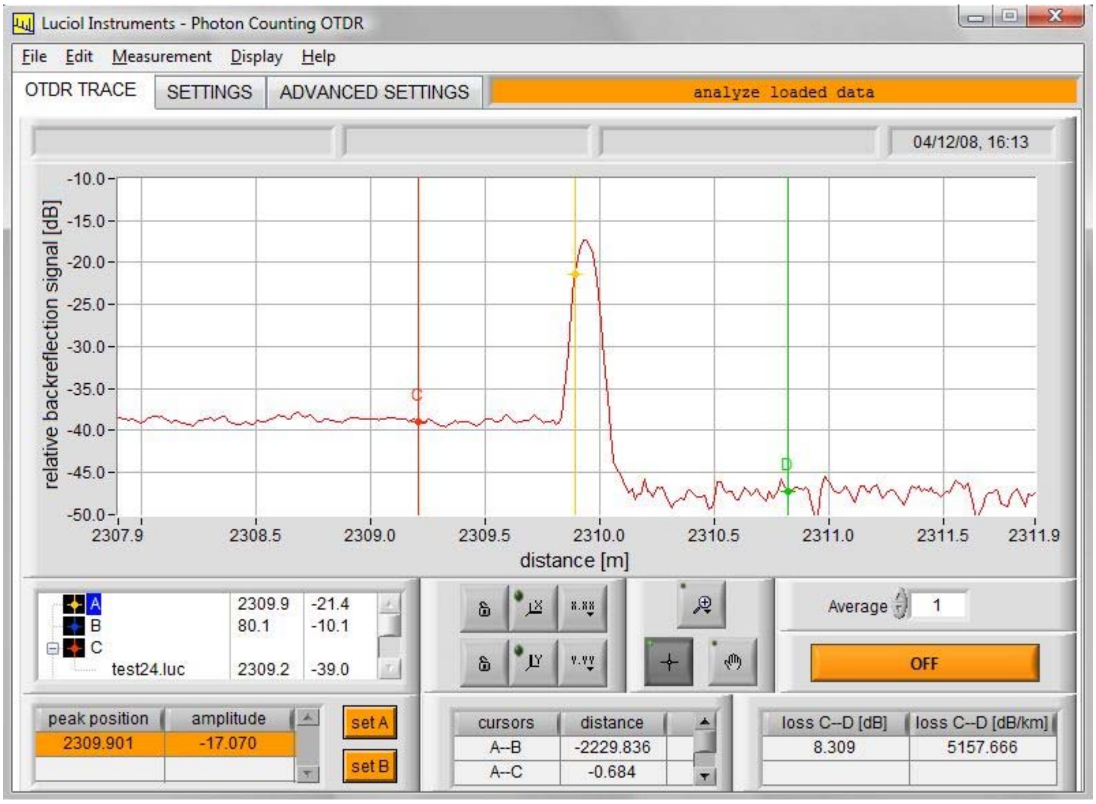
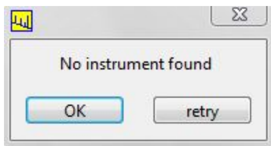


Figure 3: The OTDR Trace Tab

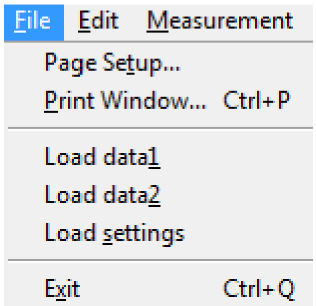
The OTDR trace of the Device Under Test will be displayed in real time on the screen, in the OTDR TRACE tab. The SETTINGS tab allows the user to select the required settings prior to the measurement, including fiber id, operator and comments. The ADVANCED SETTINGS tab is reserved for more advanced features and selecting the emitter for multi-wavelength systems. Four cursors enable to measure quantitative features on the trace (using also the MEASUREMENT menu). Various graphical tools are also available. They should be used to select the scale of the displayed trace, zoom on selected features, or change the spatial average to smoothen the trace. To start the measurement single-click on the OFF/ON button, showing the state of the OTDR. Additional status information is shown in the status bar on top of the OTDR graph.

Note: If there is no instrument connected to the computer when the program is started, the warning shown on the right appears. Press OK if you want to analyze previously saved data. If you want to perform a measurement with the ν-OTDR check the USB connection and press RETRY.



> **Important:** Read section 0 of this manual before using ADVANCED SETTINGS. Failure to do so may result in wrong traces.

4.3 The FILE menu

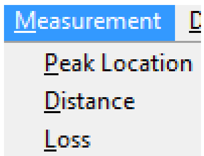


This menu allows you to choose the printer set-up, print the screen and load the result of up to two previous measurements.

Clicking on LOAD DATA prompts you to choose a file name containing the saved results of a previous measurement. The default file extension is **.luc**. Note that in the installation CD-ROM provided with the unit, in the EXAMPLES directory, you have several measurement examples, which can be loaded.

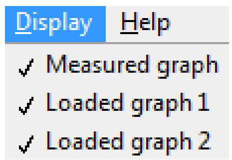
If you want to recall previous settings, but do not wish to have the initial data, click on the LOAD SETTINGS menu, and choose a file containing the saved results of a previous measurement. This can be helpful if you use similar settings for several measurements, and wish to avoid re-typing all the settings.

4.4 The measurement menu



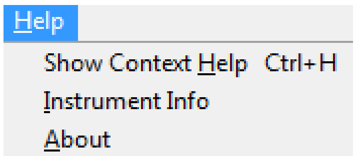
This menu enables to choose several types of automatic measurement features. PEAK LOCATION locates all the peaks on the trace. These can be identified with the help of the yellow and blue cursors. DISTANCE gives the distance between the four cursors. LOSS measures the loss between the green and red cursors. These features will be discussed further in the Data Analysis section 0.

4.5 The DISPLAY menu



This menu enables to choose the information displayed on the screen. You can select the data, both measured and loaded from a previously saved file. The default is to show both loaded and measured graphs.

4.6 The HELP menu



With this menu, you can get explanations about the various features of your measurement window. Click on SHOW 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 the INSTRUMENT INFO, you can also get information about the OTDR, such as wavelength or fiber type.

4.7 The .ini file

Most of the settings chosen for the measurement are saved into the OTDR.INI file. This file is stored in the same folder as the OTDR.EXE file, typically in the folder: PROGRAM FILES\LUCIOL INSTRUMENTS\OTDR. Each time you open the software, all the settings, which were selected when the program was closed the last time, are selected again.

> **Note:** If you need to go back to all the default settings, you can simply delete the OTDR.INI file. This file will be created again next time you use the OTDR program.

5 Testing a Fiber

5.1 Preparation

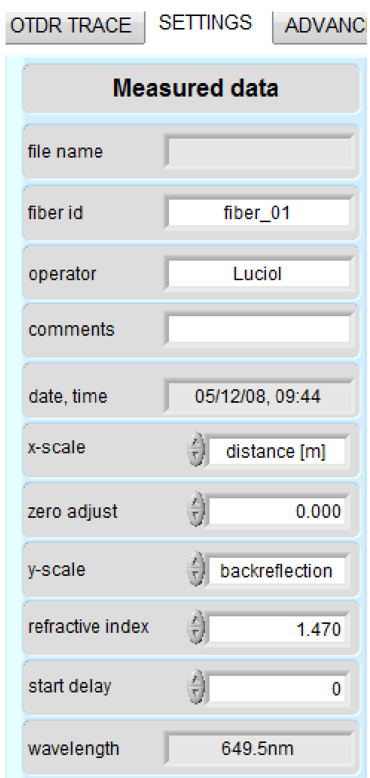
Before making a measurement, switch the OTDR on. The LED on the front panel should flash for about one minute, and then remains lit. In order to have precise measurements, we recommend waiting a few minutes, after powering the OTDR, before making a measurement.

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. Any fiber end should thus be covered, and the fiber should have an opaque jacket. If this is not possible, we recommend working in a darkened environment.

Connect the computer to the OTDR via USB port. To start the program, double click the OTDR icon on the desktop or select OTDR from the START MENU/PROGRAMS/LUCIOL INSTRUMENTS. The measurement window shown in Figure 3 opens.

5.2 Settings



Before starting the measurement, you should open the SETTINGS tab, to select the various settings, as shown aside. In the FIBER ID, OPERATOR, COMMENTS, boxes, you can specify the name of the fiber, and any comment you wish to identify your measurement.

The X-SCALE control allows selecting the distance unit to meter [m], feet [ft], inch [in]; or time in nanoseconds [ns] (in which case the choice of refractive index becomes irrelevant).

The ZERO ADJUST control allows shifting the entire trace by the selected value. This is useful if a precise length measurement relative to a certain position (e.g. a reflection) is required. For example this control can be used to set the position of the reflection created by the output connector of the OTDR exactly to 0. The relative distances of all the other peaks are now known with a few mm precision.

The Y-SCALE choice, allows you to measure directly the parameter of interest. If you need the measure the height of backreflections, use the BACKREFLECTION setting. If you wish to characterize losses in the fiber, use the LOSSES setting. The slope of your curves then gives directly the loss coefficient in your fiber. The only difference between these two settings is a factor of 2 in the y-scale (in dB). The BACKREFLECTION setting measures the real relative power level at the detector, while the LOSSES setting takes into account the fact that the detected light performs a return trip before being detected. Therefore the measured losses correspond to twice the losses in a single trip. Since the parameter of interest is the single trip losses, we need to divide the measured value by two.

The START DELAY feature allows you to start your scan at various points in your fiber. The unit for START DELAY is the same as in the X-SCALE (meter, feet, inch or nanoseconds). This feature is useful for two purposes. First, it can be used to remove a strong peak, which may reduce the useful dynamic range. For example, the input connector often offers a strong reflection[‡]. If this reflec-

[‡] The strong reflection at the input may be caused by a bad contact between the fibers. In order to weaken this reflection, clean the connector properly. You may also use some index-matching gel in the connector.

tion is seen, the lowest feature you may see in your scan (due to the dynamic range of about 40 dB to 50 dB in BACKREFLECTION setting) is about 40 to 50 dB lower. With this strong peak removed, you may see much weaker features. Second, for the OTDR at 1550 nm, the maximum distance, which can be analyzed in a single window, is only about 200 m. The total distance range (up to 40 km depending on the option chosen) can be covered by using sliding windows, starting at different points (e.g. by setting the START DELAY to 400, one can analyze the fiber between 400 and 600 meters).

Figure 4 shows an example of the use of the START DELAY feature. The fiber under test (FUT) is a 110 m-long SMF, with two FC/PC connectors. Two short patchcords of about 2 meters, with one FC/PC and one FC/APC connector are added, one on each end, to connect to the OTDR on one side, and to reduce the end-reflection on the other.

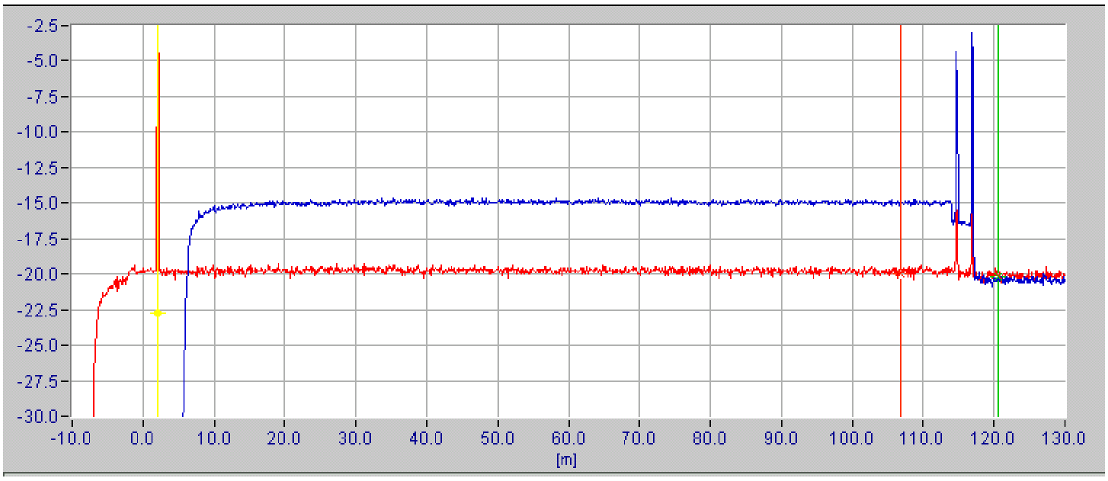


Figure 4: Using the START DELAY feature

The **red** trace is obtained with the START DELAY at zero. The reflection from the first FC/PC connector is so high, that the dynamic range of the instrument is not sufficient to see the RBS level in the fiber. In addition, the reflection from the first APC connector (at 0 m) is also below the noise level. The only features of interest are therefore the reflections towards the end of the FUT. In contrast, the **blue** curve is obtained with the START DELAY at 12 m. The first reflection peak is outside of the detection window. The RBS level is now seen clearly along the fiber (it is about 5 dB above the noise level). One can thus find out that there is loss at a splice immediately before the second FC/PC connector. Note that the absolute level of these traces depends on the OTDR settings, and is therefore not meaningful.

Note 1: The START DELAY increases in steps of at least 4 meters. The starting point depends on each instrument (-7 m in the example). Therefore, in this example, to remove a peak at 2m one needs to add (7+2=) 9 m of delay. The nearest multiple of 4 is therefore 12 m. In addition, it takes about 10 m to reach the flat level, where measurements are meaningful. So the measurement is correct only from 15 m.

Note 2: The step size may be longer for specially designed instruments or for long range setting (see in ADVANCED SETTINGS, section 5.5). In this case, the start delay option should only be used for starting the trace far away in the fiber, even several kilometers from the connector.

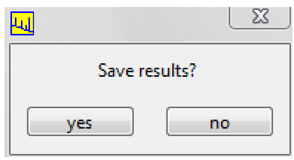
5.3 The measurement

To start the measurement, click on the ON/OFF button. The initialization procedure may take several seconds, during whom the program displays the message: SETTING PARAMETERS. After this, the measurement itself starts. Data acquisition continues, till the status button is pressed again.

> **Note:** It is also possible to start and stop the measurement by using the F1 key. In conjunction with the AUTO SAVE feature (see section 5.5.2) this allows the user to make remote measurements, for example from an external program.

Note that each trace is in fact a histogram. The height of the curve is the number of counts in each of the bins. Initially, with very few counts in each bin, the trace is very noisy. Therefore, in order to get a precise result, one needs to integrate for some time. This integration time depends on the details one want to see. For large reflections, the number of counts in the bins shall quickly become large, and only a short time is necessary. In contrast, the Rayleigh Back Scattering is much weaker, especially after long distances, and requires longer integration times (of the order of one minute). In some cases, like measurements of very weak losses at one point, longer times may be required. Note also that, once the measurement has started, you should not modify the FUT or the settings. If you change anything in the FUT, it is recommended to stop the measurement, and start again. To monitor changes in the FUT, it is possible to use the REPEAT MEASUREMENT feature in ADVANCED SETTINGS.

5.4 Saving the data



When the measurement is completed, click on the ON/OFF button (or click on the F1 key, as explained above). A new window opens. To save the results, press YES, select a directory where to save your file and choose the file name. This file is a text file, which can later be opened and analyzed with the OTDR program, using the LOAD DATA menu. It can also be used with any data processing software. An example of a saved file is presented in appendix A.4, which shows the position of the data points in the file. You can choose any file extension for your measurement file. For consistency, we recommend the .LUC extension, which is the one suggested by the software by default. This way, you will always be able to identify a ν-OTDR measurement file easily.

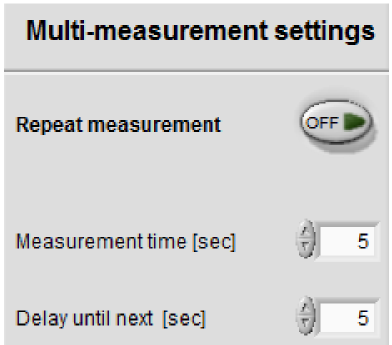
> **Note:** If the Auto save feature is enabled, (see page 12,The AUTO SAVE function), the results are automatically saved with the selected initial file name and an automatic increment.

5.5 Advanced settings

Clicking on the advanced settings tab opens a new window, with a number a different settings.

> **Note:** Some of the settings in this section are only available with special options in the hardware. If an option is not available with your particular system, the corresponding buttons will be dimmed.

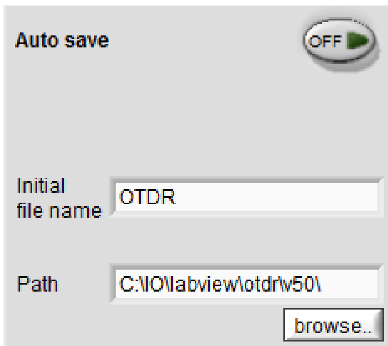
5.5.1 Multi-measurements



This option allows the user to modify the DUT and see the induced changes in the trace in real time. When REPEAT MEASUREMENT is ON, as obtained by clicking on the button, the OTDR integrates the data for the MEASUREMENT TIME selected in seconds, and then displays the new trace. This feature is useful, if you want to see changes in the FUT in real time (e.g. introduce a bend and see if it induces loss). However, if the integration time is too short, the trace may become too noisy. The optimal integration time can be found by making single measurement and regarding the integration time it takes until the trace is sufficiently smooth.

In addition, the user can select a DELAY UNTIL NEXT time between two measurements (in seconds). The minimum delay time is 0 s. When used in conjunction with the AUTO SAVE feature, this is useful to track changes over time.

5.5.2 The AUTO SAVE function



If the user does not want to select a file each time the measurement is stopped, the AUTO SAVE feature can be used. Click on the BROWSE button, to open the SAVE window, go to the required folder (or create a new folder), and then click on SELECT CUR DIR. The path will appear in the PATH display line. Choose the initial file name, e.g. OTDR, as required. The names of the saved files will be incremented each time a measurement is done. For example, if the initial name is OTDR, the file names will be: OTDR1.luc; OTDR2.luc...

This feature can also be used in conjunction with the MULTI-MEASUREMENT option. It enables to save all the results obtained during a series of measurement over time.

5.5.3 Selecting the emitter (wavelength)

The ν-OTDR can be provided with up to 4 different emitters[§]. These can be different wavelengths, or different types of sources, such as DFB lasers, FP lasers, or even LEDs. If your system has several sources, the table shown on the right will be activated. Select the desired source by clicking on the corresponding line in the table.

Emitter selection

operating wavelength	emitter type
1310nm	FP
1541nm	LED
1622nm	FP

Note: The emitter cannot be changed during an acquisition.

5.5.4 The measurement range

The measurement range of the ν-OTDR can be modified according to the maximum length of the fiber under test. The chosen range should always be superior to the maximum length of the fiber (otherwise, *folding* may occur, whereby a far away reflection peak may appear close to the front connector). Choosing a longer range does not modify the measurement, but makes it slower (the pulse repetition rate has to be adapted to the range, in order to have only one pulse at a time in the fiber under test).

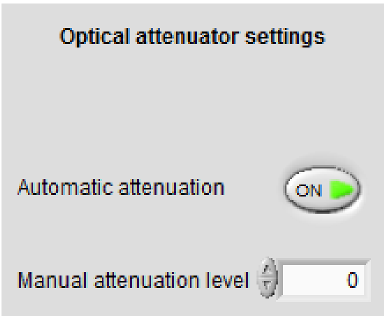
Distance selection

maximum fiber length [km]
1.3
2.6
5.2
10.4
20.8
41.6

Note: Some of the ranges may not be available for certain types of ν-OTDR. In this case, the corresponding line is dimmed, and cannot be selected.

5.5.5 Controlling the optical attenuator

In some cases, the final reflection of an optical link is very large (for example a Fresnel reflection, obtained with a flat polished interface between glass and air is around -15 dB, compared to a typical RBS of -80 dB for SMF at 1550 nm with the ν-OTDR). The dynamic range of the instrument does not allow seeing both the RBS and a Fresnel reflection on the same trace. In normal operation the instrument uses an automatic attenuator which always reduces the detected light level to less than one photon per emitted pulse. If the attenuator is manually set to a lower level the strong reflection will saturate the detector (more than one photon per pulse). This way it is possible to reduce this reflection relative to the RBS level of the fiber before it. As shown in Figure 5, the RBS can this way be shifted above the noise level (green trace) and fiber losses can be made visible. This feature is useful in cases, where access to the end of the fiber is not possible, or where the end-reflection cannot be reduced physically, using for example a mandrel wrap.



[§] This is not possible for all wavelength ranges or fiber types. If you need to upgrade an existing system to multi-wavelength, contact us.

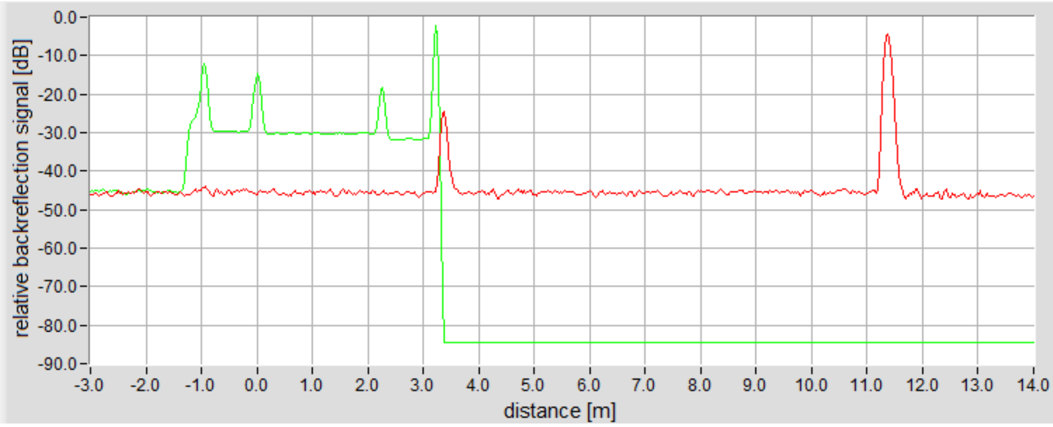


Figure 5: Using the manual attenuator function.
Red trace: Automatic attenuator, Green trace: Manual attenuator.

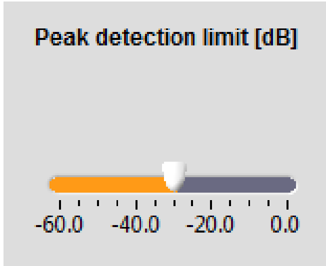
> **Important:** Setting the attenuator mode to manual may lead to incorrect traces. This feature should be used only to remove a reflection peak, which is much larger than any other peak. If performed correctly, it will give a correct trace up to the peak, while the peak itself and the trace after it are meaningless. Do not use this feature if you are not already familiar with the OTDR, and follow the instructions carefully.

In order to use this feature, do the following:

1. Select automatic attenuator OFF
2. Choose the required manual attenuation level, between 0 and 127. The attenuator is not calibrated, so it is not possible to know the corresponding attenuation level. However, the attenuation level is reproducible, so that it is possible to reproduce the same conditions for different setups, or for the same setup at different times. Typically, the attenuation level necessary to remove a Fresnel reflection is about 80.
3. Starting from high attenuation values, when you can see only the end reflection, start lowering the attenuation value, making a trace at each step. As more and more power is received, the beginning of the trace (for example the RBS) is going up, and should appear out of the noise floor. The end reflection value is now meaningless (more than one photon impinges on the detector, which will always give a single click). The number of counts after the end peak falls abruptly to zero, while the height of the peak is reduced. This is the clear sign that the last peak height is meaningless.
4. You can lower the attenuation until you obtain the desired trace of the fiber, up to the last reflection. However, the trace is only correct if the last peak remains at least several dB above all other peaks.

5.5.6 Changing the peak detection limit

The OTDR can automatically detect the reflection peaks (see 6.5.1). The automatic detection gives the best precision on the position and height of the peaks. However, traces with a high resolution OTDR are generally noisy. So, depending on the trace, the OTDR may detect too many peaks, or may not detect all the correct ones. The peak detection limit (in dB) can therefore be adjusted, to ensure that all the relevant peaks in the trace are automatically detected. Only peaks above the peak detection limit will be detected automatically.

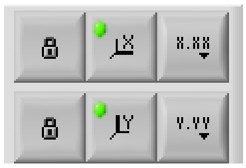


> **Note:** This feature can be used and modified both during the acquisition of a trace, and after loading a file.

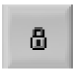
6 Data Analysis

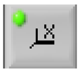
All the features, which enable a full analysis of the data, can be used in real time, during the acquisition of the trace. They can also be used on saved traces, which were previously loaded using the LOAD DATA menu.

6.1 The scale tools



These are shown on the right. To execute the required operation, simply click on the button:

 Lock autoscale

 Autoscale x once

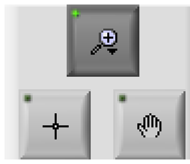
 Autoscale y once

 Format x-scale

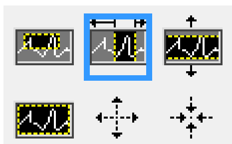
 Format y-scale

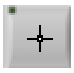
Note that, when the acquisition starts, the default option is to have the AUTOSCALE ON for the y-axis and off for the x-axis.

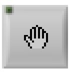
6.2 The graph tools



These tools allow to zoom in and out, to move the trace around, and to select the cursors:

 Open the zoom submenu  with the options: zoom into selected area, zoom x, zoom y, and zoom to entire trace, zoom out and zoom in.

 Change pointer to cross for moving the cursors

 Change pointer to hand for moving the entire trace

Note 1: Another possibility for focusing on one part of the trace is to change directly the values at the beginning or the end of the axes. Simply click on the label, insert the desired value, and then press enter.

Note 2: To use the zooms, or perform any scaling operation, AUTOSCALE has first to be disabled.

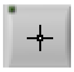
6.3 Spatial averages

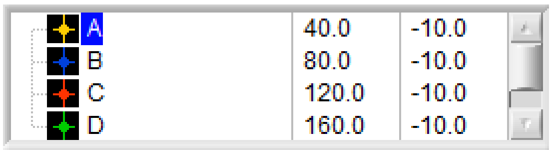
The AVERAGE button, shown on the right, allows performing moving spatial averages on the trace. The number in the box is the number of points used on each side of the measurement or centre point**. This feature can be used to smooth a trace, for example to see weak loss in the FUT. However, the spatial resolution is degraded.

** E.g. the number 1 means that the average is performed on one point on each side, or 3 points altogether.

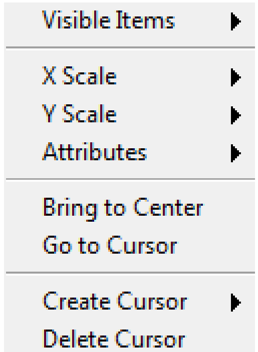
> **Note:** This feature only modifies the way the data is displayed. It does not change the way it is stored. All traces are saved with no averaging.

6.4 The cursors

The trace includes four cursors, labeled A to D, which can be used to identify peaks or to calculate loss in the fiber easily. All cursors are controlled directly on the screen, by selecting the cursor button  in the graph tools. Move this cross around the graph, and "click and drag" on one of the cursors to displace it. Information about the cursors is displayed in the cursor box, as shown on the right. The position of each cursor is displayed. The properties of the cursors are initially set by the program, but they can be modified by right-clicking on the line of the corresponding cursor in the cursor box. This opens a new menu, as shown on the right.



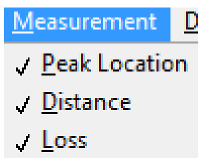
The most useful features of this menu are BRING TO CENTER, which moves the cursor to the center of the displayed section, and GO TO CURSOR, which re-centers the displayed section on the cursor. You can also modify the cursor attributes, for example by changing the cursor style, the point style, the linewidth or the color.



Note that two of the default cursors, A and B are free, while the other two, C and D are locked to a trace. The two free cursors are used for automatic peak detection, while the locked ones are used to measure attenuation along a trace. The locked cursor can be attached either to the measured data (currently under acquisition) or to one of the loaded data. Right-click on the diamond of a locked cursor, and the menu shown on the right opens. You can select the SNAP TO feature, to lock the cursor to one or any of the currently displayed traces.

It is also possible to add one or more cursors, by selecting the CREATE CURSOR. You can choose the type of cursor (free or locked to traces) and all its properties.

6.5 The measurement menu



This menu allows activating three measurement windows: peak detection, distance measurement and loss measurement. Checking one of these options opens the corresponding measurement windows on the bottom of the OTDR TRACE tab, as shown in Figure 6. Here, all three measurement options are activated. The example shows the trace of a 10m patchcord with a bend loss at about 3m distance. The PEAK LOCATION window indicates the position of the found peaks and their amplitudes. Cursors A and B are set to the reflections created by the front connecter and the end connector, respectively. The DISTANCE window shows the distance of the four cursors, A-B is the length of the patchcord. The LOSS windows shows the difference of the RBS level between cursors C and D (the bend loss), the step is found to be 3.6 dB.

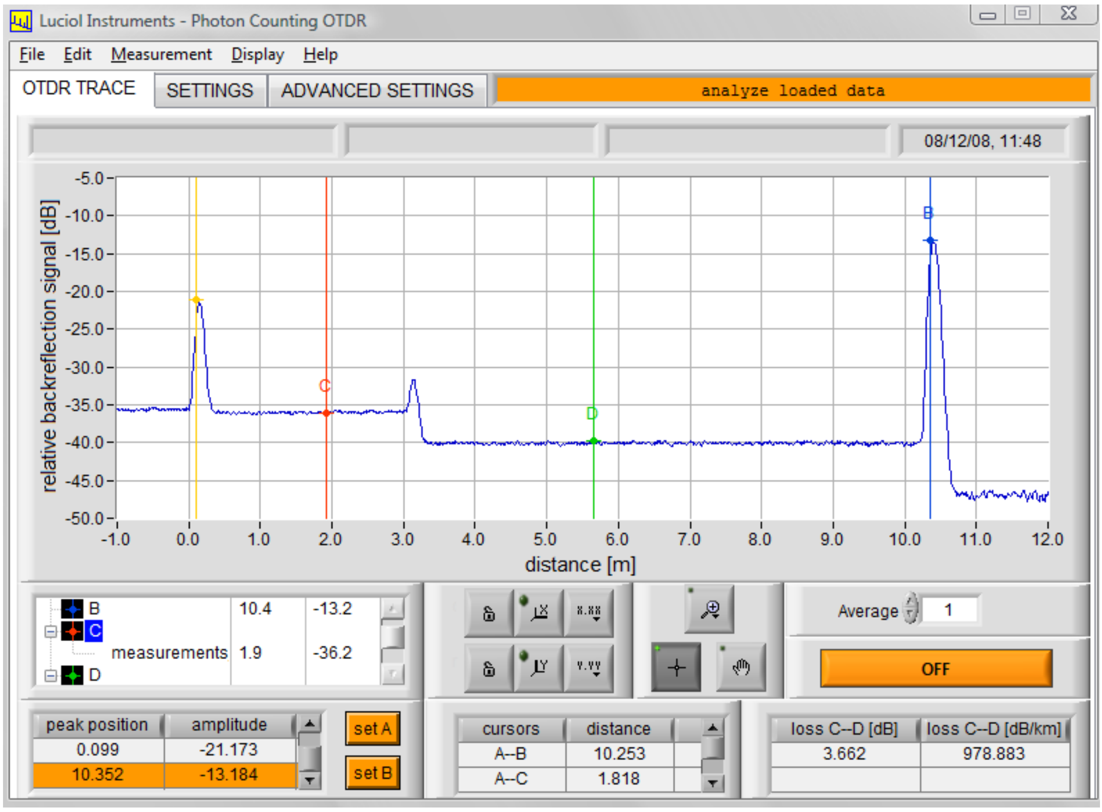
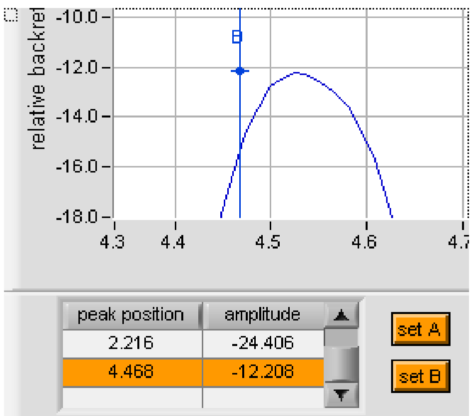


Figure 6: Using the measurement functions

Note: These features can be used both in real-time, during a measurement, and after loading a saved file. However, once a measurement is finished (after pressing the STOP button) they are not activated.

6.5.1 Peak detection

With this option, the software automatically detects the reflection peaks on the trace. The position and height of each peak is given in a table as shown on the right. In addition, cursors A and B can be brought to the highlighted peak, by clicking on the corresponding button, SET A or SET B. For example, clicking on SET B brings cursor B (blue) on the peak located at -4.47 m, as shown on the right. The graph will automatically be centered on the selected peak within a 10m wide window. In order to have consistent results with highest precision for optical pulses of various widths, the position of the cursor is set on the rising edge of the pulse, 3 dB below the maximum.



Note: The automatic peak detection feature gives the best precision for peak location. However, it may not detect weak peaks, and may occasionally find spurious peaks, especially when the trace is noisy. In these cases, try changing the PEAK DETECTION SENSITIVITY, in the ADVANCED SETUP tab.

6.5.2 Distance measurement

This feature automatically calculates the distance between each pair of cursors. It can be used in conjunction with the automatic peak detection feature, or by moving the peaks manually (see 6.2, *The graph tools*).

6.5.3 Loss measurement

This feature automatically calculates the loss between cursors C and D, together with the loss per unit length. This can be used to calculate distributed loss along a fiber, loss at a connector, or loss at a splice.

6.6 Comparing traces

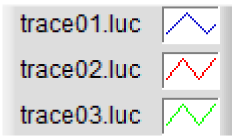
It is possible to load up to two previous traces, using the LOAD DATA menu, with LOAD DATA1 and LOAD DATA2. These traces will be displayed in different colors, and can be processed with all the data analysis features presented in the next section.

In addition, you can also perform a measurement. The trace under acquisition will be displayed in **blue**. This enables to compare the traces, for example to see any modification in the Device Under Test.

> **Note:** During a measurement, the active trace, for which the data analysis features can be applied (e.g. peak detection, average...) is the trace under measurement. When analyzing loaded data, the active trace is the last trace, which was loaded.

When using this feature, it may be useful to add the Plot legend, to display the file name of each trace. In order to do this, position the mouse anywhere on the graph area, and right-click to open the window on the right. Click on VISIBLE ITEMS and select PLOT LEGEND.

The Plot legend, as shown on the right now opens on the upper right-hand side of the measurement window. Each of the traces on display is now labeled. You can find all the settings for each of the traces by selecting the settings tab (see section 5.2).



> **Note:** When the Plot legend is selected, you can click on any of the traces, to modify the way it is displayed (line type, thickness, color...).

6.7 Printing the results

There exist several possibilities for printing the results, either directly on a printer, or within a file.

6.7.1 Print window

The full window can be printed directly, using the PRINT WINDOW command in the FILE menu. You can either print directly to your printer, or print to a file.

6.7.2 Copy data

Another option is to use the COPY DATA command. A right-click on the trace opens a new window. Click on COPY DATA to copy the trace to the clipboard. This trace can then be inserted into any document (e.g. Word).

> **Note 1:** In order to copy only the visible trace, make sure that the AUTOSCALE is unchecked for both x and y-axes. If AUTOSCALE is active, the full trace will be copied.

Note 2: To copy only the trace, make sure that GRAPH PALETTE and CURSOR LEGEND in the VISIBLE ITEMS window are unchecked.

6.7.3 Using print screen

You can use the print screen command of your computer, or alternatively the Alt- print screen, to copy the screen or the active window respectively to the clipboard.

7 Troubleshooting

7.1 Hardware

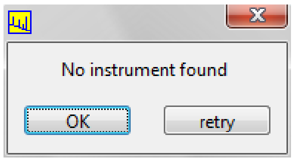
The ν-OTDR system is simple and easy to use. If the LED on the front face of the OTDR is lit, the measurement should be carried out correctly.

If the LED on the front face does not light up when the OTDR is switched on, or flashes for more than about one minute, check the power adaptor and the power cord. If this does not solve the problem, contact Luciol Instruments for support.

7.2 Software

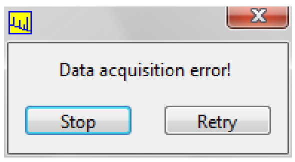
The following error messages might appear during a measurement. If this happens, first follow the advice given in the following sections. If the error persists, contact Luciol Instruments with a description of the error message, of the FUT and of the conditions of the measurement.

7.2.1 No instrument found



This message means that the computer could not identify the ν-OTDR. Check that the OTDR is switched on and connected to the power supply and check the USB connection. Press OK and try again. Try closing and restarting the OTDR program. If the device is still not recognized, close the program, switch the OTDR off and on again and restart the program. This will reinitialize the connection.

7.2.2 Data acquisition error



This message corresponds to a time-out during the communication between the computer and the OTDR. It can have two causes:

1. The communication was lost during the measurement. Check the USB connection and start a new measurement
2. The OTDR stopped sending data during the measurement. This normally means that the optical connection was lost during the measurement. Check that the FUT is still connected to the OTDR.

Appendices

A Specifications

A.1 General

- **Interface:** Module connects to an external computer via USB
- **Operating system:** Windows 98® SE or higher; hardware requirements: Pentium processor, >32 MB RAM, Min 800x600 display resolution
- **Dimensions**: 325x70x235 (width×height×depth in mm)
- **Weight**: 2 kg
- **Electrical**: 15V DC, 20W, with external power supply (100-240V AC, 50/60 Hz)
- **Environmental**: Operating temperature -5 °C to 40 °C,
  storage temperature: -20 °C to 60 °C, humidity: 0-90% non-condensing

A.2 Long wavelengths: 1000 – 1650 nm

- Wavelengths...........1310 nm, 1550 nm, 1610 nm (others available upon request)
- Distance range.................................... 1.3, 2.6, 5.2, 10.4, 20.8 (41.6 optional) km
- Measurement section width ....200 m

Resolution

- Event dead zone .... 10 cm
- Attenuation dead zone (ORL = 45 dB).. 40 cm
- Total number of samples/trace..32768
- Sample spacing...130 ps / 13 mm

Dynamic Range

- Return loss (single trace).. 35/40 dB
- Return loss (total).. 95/100 dB
- Rayleigh .... 12.5/15 dB
- Sensitivity ....-105/-110 dB

Accuracy

- ORL (relative) .... ± 0.4 dB
- Insertion Loss .... ± 0.1 dB
- Minimum Insertion Loss ....0.05 (LED), 0.1 (FP), 0.3 dB (DFB)
- Short Distance... ± (3 mm + [fiber length]·$5 \cdot 10^{-5}$)
- Long Distance.. ± (3 mm + 10 mm + [fiber length]·$5 \cdot 10^{-5}$)
- Distance zero-offset .... ± 13 mm

A.3 Short wavelengths: 500 – 1000 nm

- Wavelengths .... 500 nm, 650 nm, 850 nm (others available upon request)
- Distance range ....1.3, 2.6, 5.2, 10.4, 20.8 (41.6 optional) km
- Measurement section width.. 800 m

Resolution

- Event dead zone .... 15 cm
- Attenuation dead zone (ORL = 45 dB) .... 30 cm
- Total number of samples/trace 32768
- Sample spacing .... 260 ps / 26 mm

Dynamic Range

- Return loss (single trace) .... 50 dB
- Return loss (total) .... 100 dB
- Rayleigh... 25 dB
- Sensitivity..-110 dB

Accuracy

- ORL (relative) .... ± 0.4 dB
- Insertion Loss .... ± 0.1 dB
- Minimum Insertion Loss ....0.05 (LED), 0.1 (FP), 0.3 dB (DFB)
- Short Distance... ± (3 mm + [fiber length]·$5 \cdot 10^{-5}$)
- Long Distance.. ± (3 mm + 10 mm + [fiber length]·$5 \cdot 10^{-5}$)
- Distance zero-offset .... ± 26 mm

A.4 Example of a saved file

The following is an example of a saved file. The data starts on line 31, with the X and Y columns. You can use the data to include into any data processing software.

```
    Luciol Instruments photon counting OTDR v 5.0 -do not modify
this file-
    15/08/08, 18:12









    0.000000
    1.000000
    1.470000
    0.000000
    801.000000
    0.000000
    2.000000
    130.558955
    0.000000
    0.000000                         Parameters needed by the program
    0.000000                                  DO NOT MODIFY
    0.000000
    0.000000
    0.000000
    0.000000
    0.000000
    0.000000
    0.000000
    0.000000
    0.000000
    -10.664      -46.481             Start of data points
    -10.611      -46.481
    -10.558      -46.481
    -10.504      -46.481
    -10.451      -46.481
    -10.398      -46.481
    -10.345      -46.481
    -10.291      -46.481
    -10.238      -46.481
    -10.185      -46.481
    -10.132      -46.481
    -10.078      -46.481
    -10.025      -46.481
    …
```

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, refer to the test sheet of your instrument or use the HELP menu, INSTRUMENT INFO when the instrument is connected to the computer.

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 distributor.

RoHS compliance for China:

Toxic or hazardous Substances and Elements

铅	汞	镉	六价铬	多溴联苯	多溴联苯醚
Pb	Hg	Cd	Cr^{6+}	PBB	PBDE
X	X	X	X	X	X

O =小于 最高浓度值 Below maximum concentration values X =高于 最高浓度值 Above MCV

Main product

Toxic or hazardous Substances and Elements

铅	汞	镉	六价铬	多溴联苯	多溴联苯醚
Pb	Hg	Cd	Cr^{6+}	PBB	PBDE
O	O	O	O	O	O

O =小于 最高浓度值 Below maximum concentration values X =高于 最高浓度值 Above MCV

AC-CD Power supply

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