LUNA

OPTICAL BACKSCATTER REFLECTOMETER™
(Model OBR 5T-50)

The Luna OBR 5T-50 delivers fast, accurate return loss, insertion loss, and length measurements with 20 micron spatial resolution.

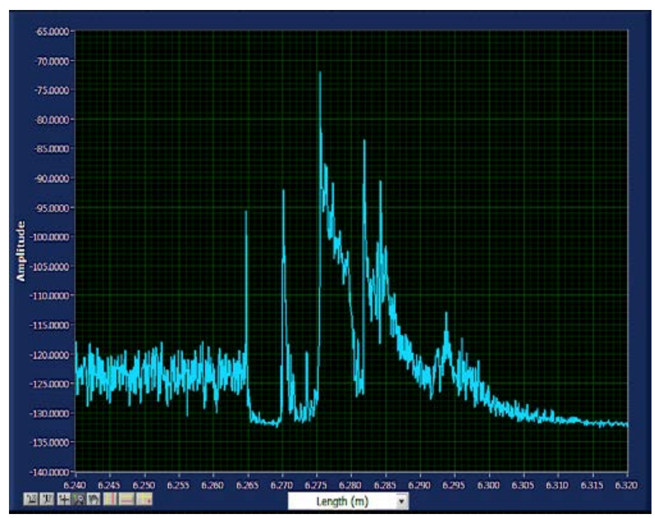
The Luna **OBR 5T-50** is a fast, simple-to-use, low cost precision reflectometer that measures the Insertion Loss (IL) and Return Loss (RL) distribution of passive optical components and modules including PLCs, optical cables, connectors, switches, couplers and more. This instrument utilizes swept-wavelength interferometry to measure backscattered light as a function of distance with -125 dB sensitivity and 20 micron spatial resolution. The OBR 5T-50 reduces cost and complexity, while increasing throughput by measuring RL, IL and length with a single instrument.

PERFORMANCE HIGHLIGHTS

- **Industry-leading combination of measurement speed, range, accuracy and resolution.**
  - **11.9 Hz acquisition rate**
  - **8.5 meter measurement range**
  - **0.015% length measurement accuracy**
  - **20 micron spatial resolution**
- **Streamlined Graphical User Interface + Software Development Kit included**
  - **Optimize throughput with customized interface**
- **Automatically locates reflective events and yields RL, IL and event location**

APPLICATIONS

- **Fault location- Measure RL, IL, length**
- **Automated pass/fail inspection and reporting**
  - **Precision optical cables and connectors**
  - **PLC and waveguide devices**
  - **Couplers, switches, beam splitters**
- **Skew measurement with sub picosecond resolution**
- **Real-time optical alignment**



Return Loss vs. length measurement of a MEMS-based optical switch. The first two reflections are 5.0 mm apart. This measurement was recorded with 20 micron spatial resolution.

www.lunainc.com
3157 State Street | Blacksburg, VA 24060
solutions@lunainc.com
Support phone: 1.866.586.2682

PARAMETER	SPECIFICATION		UNITS
	SINGLE SCAN	10 AVERAGES	
Length Characteristics:			
Maximum Device Length	8.5		meters
Spatial Resolution (two-point)[1]	20		µm
Length Accuracy[2]	± 0.015% of Length		--
Dead Zone:			
Dead Zone	20		µm
Wavelength:			
Wavelength Range	40		nm
Wavelength Accuracy[2]	1.5		pm
Center Wavelength	1546.69		nm
Integrated Return Loss Characteristics:			
Dynamic Range[3]	60	65	dB
Total Range[4]	-14 to -120	-14 to -125	dB
Sensitivity[4]	-120	-125	dB
Resolution[5]	± 1.0	± 1.0	dB
Accuracy[5]	± 1.0		dB
Insertion Loss Characteristics:			
Dynamic Range[6]	10	15	dB
Resolution[7]	± 0.5	± 0.5	dB
Accuracy[7]	± 0.5		dB
Measurement Timing:			
	11.9		Hz
Maximum Optical Power:			
	8		mW
Physical:			
Optical Connector Type	FC/APC		
Dimensions	14 x 12.5 x 6.75 (36 x 32 x 17)		In (cm)
Weight	17.3 (7.85)		lb (kg)
Maximum Power Consumption	50		W

1 Distance between two sample points along the length axis in SMF-28.
2 Accuracy is guaranteed via NIST-traceable HCN gas cell.
3 Range between strongest reflection greater than -30 dB and noise floor.
4 Noise floor return loss at half maximum length.
5 Measured with 1 cm integration width.
6 Two way loss before backscatter reaches noise floor, and IL measurements are no longer possible.
7 Measured with 10 cm integration width.

CLASS 1 LASER PRODUCT

MEASUREMENT CAPABILITIES

The Luna **OBR 5T-50** can be used to quickly measure and report Insertion Loss (IL), Return Loss (RL) and event location of passive optical components and modules. The following section highlights key measurement attributes of the system.

1. Device Length Measurement

Figure 1 illustrates the measurement of the length of a jumper with FC/APC connectors on either end. The graph displays the optical backscatter amplitude in dB as a function of length in meters.

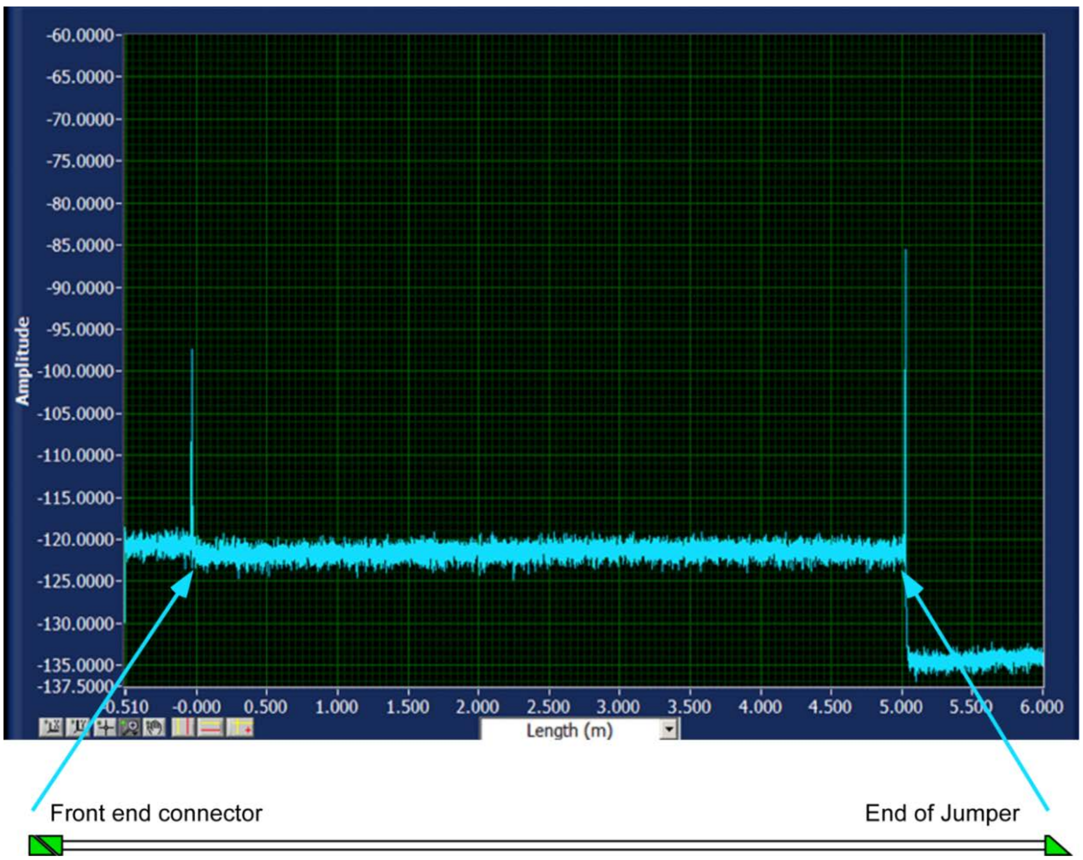


Figure 1. A five meter optical jumper with FC/APC jumpers on either end

An event table reports the event location, Return Loss (RL) and Insertion Loss (IL). In this example, the event "Reflection 1" corresponds to the end reflection of the jumper located 5.02 meters from the front panel of the instrument.

Event	Location (m)	Return Loss (dB)	Insertion Loss (dB)
Reflection 1	5.022909	-70.570648	-6.604869
Reflection 2	0.000000	0.000000	0.000000
Reflection 3	0.000000	0.000000	0.000000
Reflection 4	0.000000	0.000000	0.000000

2. Multi-Jumper Analysis

Figure 2 is an illustration of the length determination of four (4) jumpers connected in series via FC/APC bulkhead connectors.

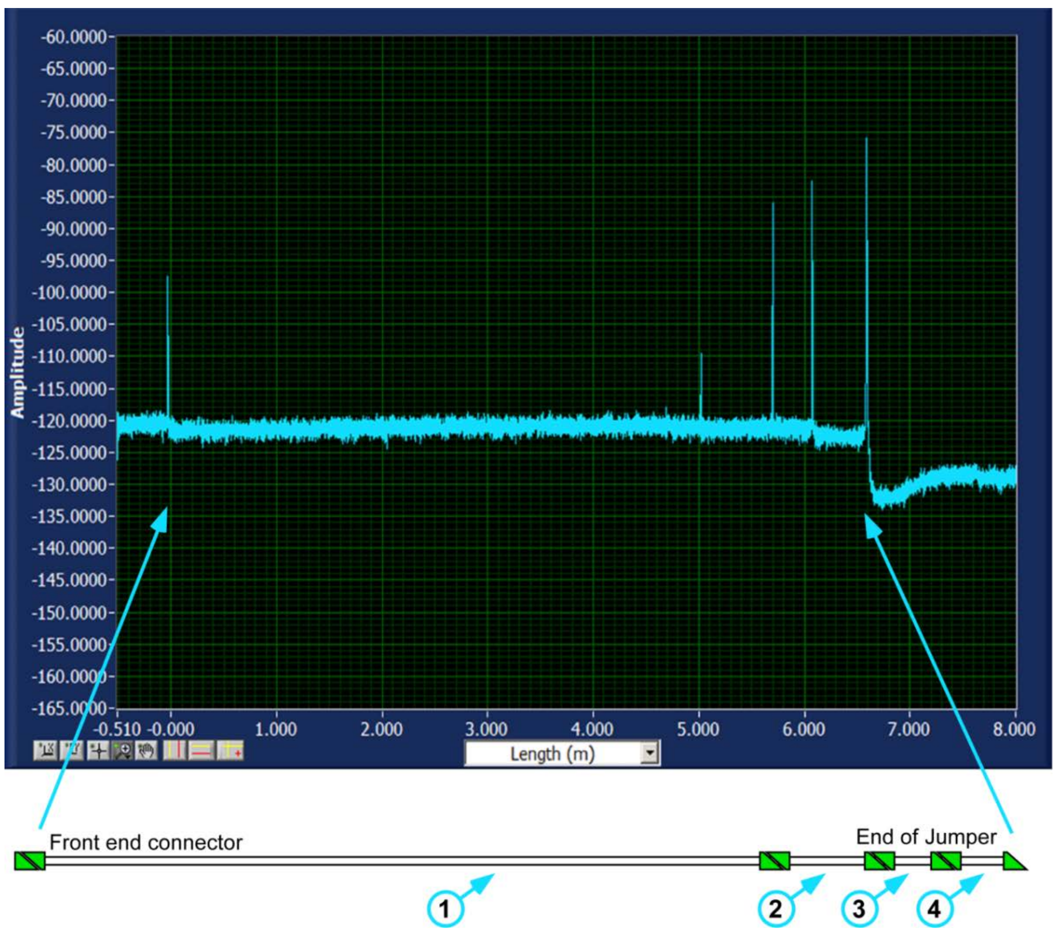


Figure 2. The backscatter as a function of length of multiple fiber jumpers

The fibers labeled 1 through 4 correspond to the reflection events reported in the event table below. The location of each event is referenced to the front of the instrument. Hence, to determine the length of each jumper one simply need subtract the length of the previous reflection event. The jumper lengths in this example correspond to 1) Jumper 1 = 5.02 m; 2) Jumper 2 = 0.68 m; 3) Jumper 3 = 0.37 m; 4) Jumper 4 = 0.52 m.

Event	Location (m)	Return Loss (dB)	Insertion Loss (dB)
Reflection 1	5.022851	-91.422852	-0.133330
Reflection 2	5.698014	-71.223022	-0.111084
Reflection 3	6.074157	-67.667549	-0.422410
Reflection 4	6.590150	-58.794689	-2.864716

3. System Spatial Resolution

The Luna **OBR 5T-50** can be used to resolve reflective events that are at close proximity to each other. *Figure 3* is a scan of a jumper that has a FC/APC connector on one end and an electro-optical component at the other. From a global perspective, the reflective event at the end appears to be a single reflective peak.

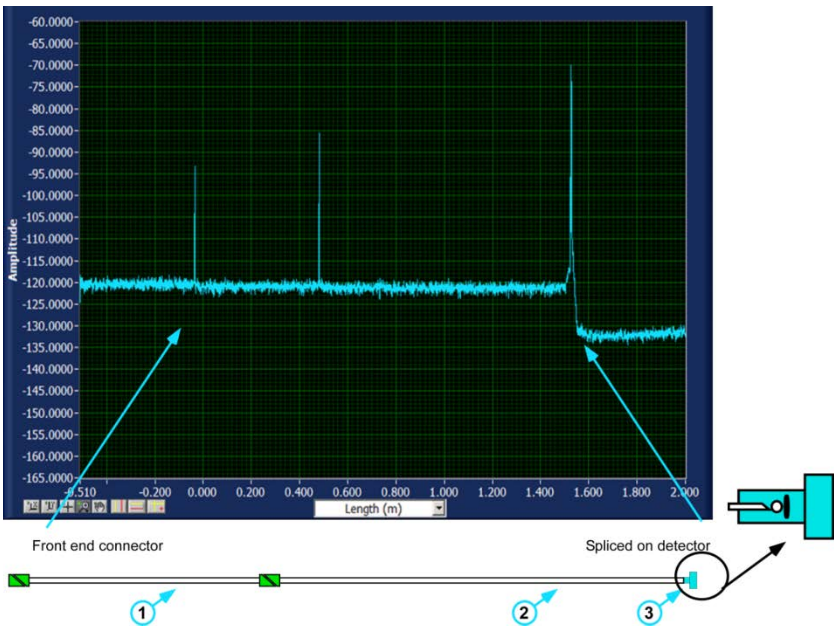


Figure 3. A zoomed-out view of an electro-optical component attached to a fiber optic jumper

Figure 4 is a close-up of the peak at ~1.5 meters. On closer inspection, we see a series of peaks that correspond to reflective events within the electro-optical component. In this illustration, peak distances as small as 0.390 mm were resolved. The system can potentially resolve peaks as close as 40 microns.

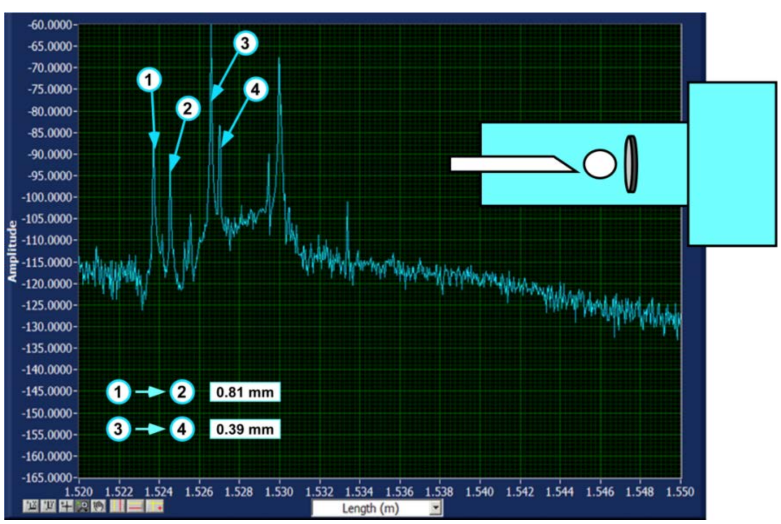


Figure 4. A close-up view of the electro-optic component attached to the fiber optic jumper

4. Feature Detection

a) Bends

The end user can leverage the high spatial resolution capability of the Luna **OBR 5T-50** to detect and recognize features in optical links. One such event is a bend in an optical path. *Figure 5* below shows a data trace of a jumper of standard single mode fiber with a bend 6.94 meters from the front of the instrument panel. From a broad view we can note the presence of a feature by significant RL and IL values at the event location.

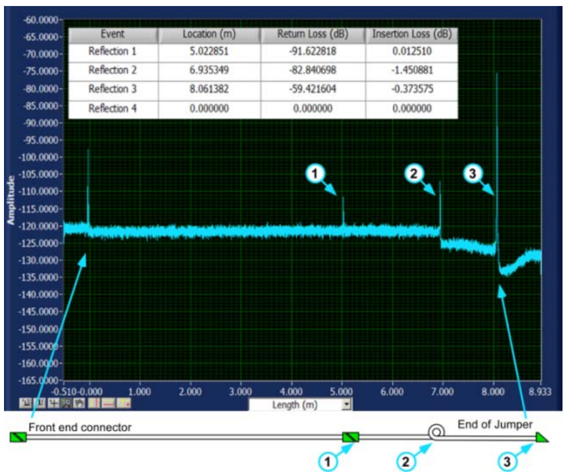


Figure 5. Zoomed-out view of optical jumper with a bend

As we zoom in to the event on the optical jumper, we see characteristics on the reflection signature that can help one identify the feature as a bend. In addition to the RL and IL, we note the characteristic shape highlighted in the figure call-out. A bend is a broadened RL event with a generally sharp rising edge and a tapered trailing edge that settles at a horizontal station lower than before. The length of the trailing edge usually corresponds to the bend perimeter. One key differentiating characteristic with bends relative to optical junctions, such as connectors, is the width of the event peak. Optical junctions have a narrow width. Bends have a noticeable gap between the rising and falling edge as can be seen in *Figure 6*.

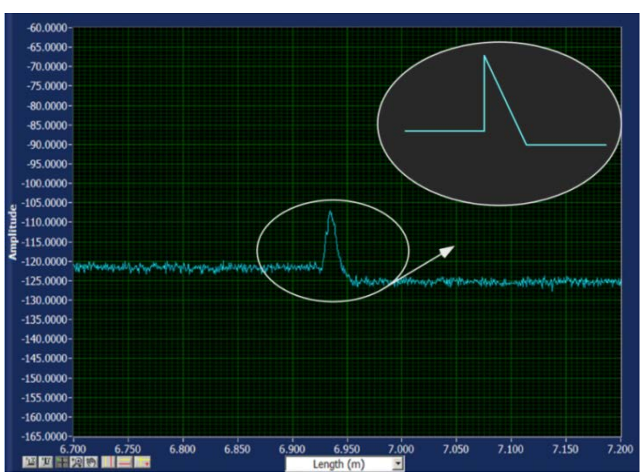
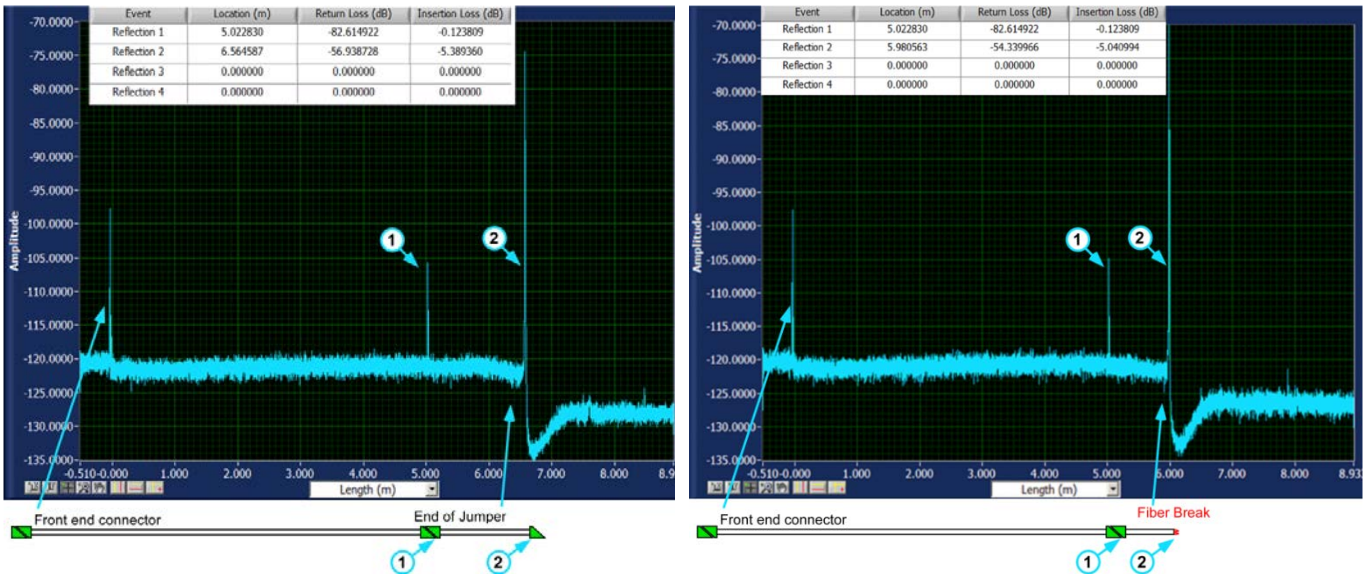


Figure 6. A close-up of the bend event on the optical jumper

b) Breaks

One can also use the Luna **OBR 5T-50** to detect breaks in optical links. *Figure 7* below shows a single mode fiber before and after a break event. The break is noted by the location migration of Reflection 2 in the event table. Due to the random nature of a break, the RL may vary over the full measurement scale.



a) before break   b) after break

Figure 7. Optical jumper before and after a break along the jumper length

Figure 8 is a zoomed in view of the break event on the optical jumper. We see characteristics on the reflection signature that can help one identify the feature as a break. The key item of note is the very narrow, near symmetric rising and falling edge of the peak as highlighted in the inset figure illustration call-out. We also note the significant width difference between the “bend” peak illustrated in Figure 6.

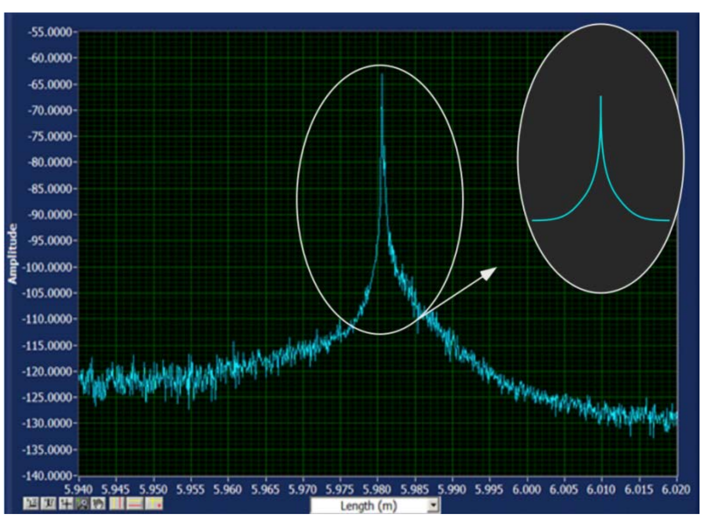


Figure 8. A close-up of the break event on the fiber.

c) Bad Splice

The Luna **OBR 5T-50** can be used to measure insertion loss in fiber. *Figure 9* shows an insertion loss measurement across a fusion splice ~1.9 meters from the front panel of the instrument. A differential loss of -0.27 dB is measured.

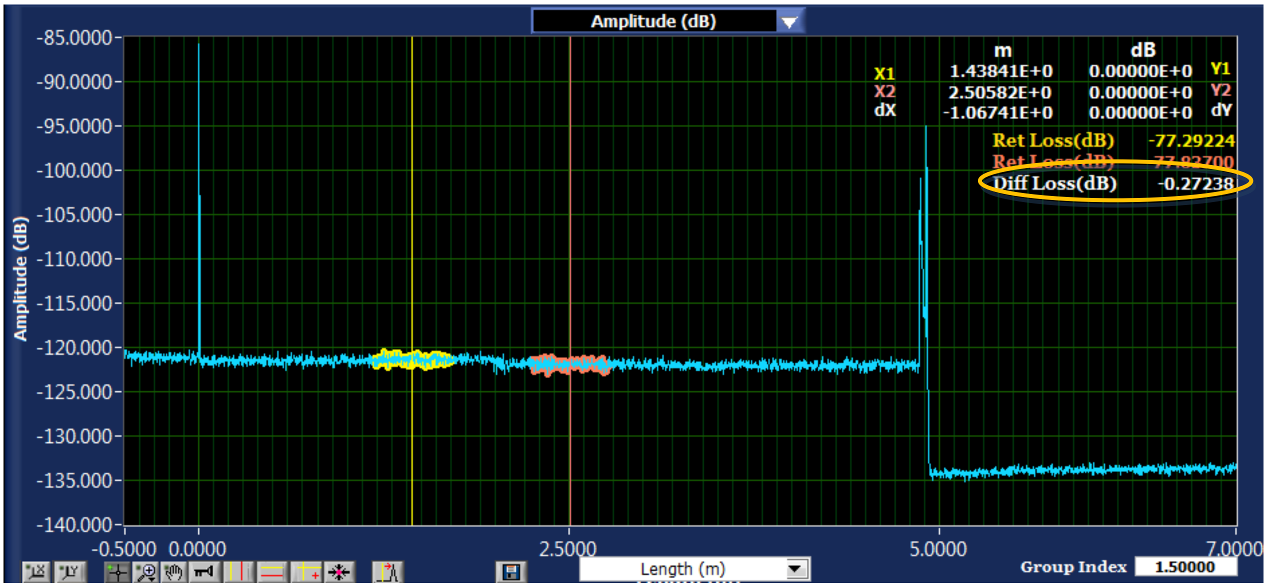


Figure 9. A zoomed-A jumper with a bad splice

As we zoom in to the event on the optical jumper, we see a decrease in the Rayleigh scatter level between 1.9 meters and 2.meters down the fiber.

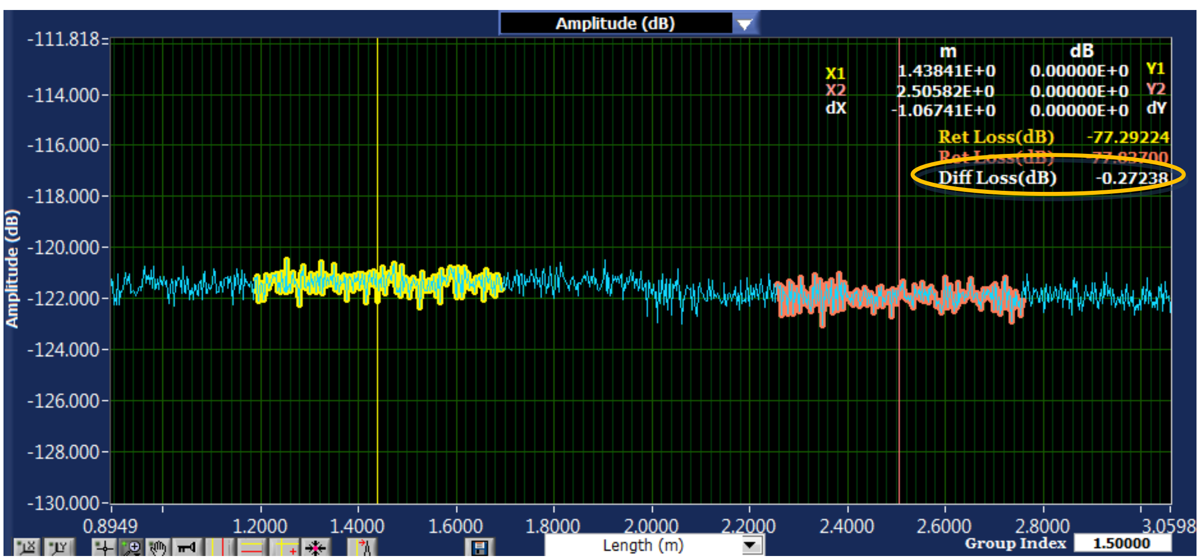


Figure 10. A close-up view of the bad splice clearly showing a drop in amplitude across the splice

5. Cleaved Fiber Analysis

a) No Attenuator

The Luna **OBR 5T-50** spatial resolution and return loss dynamic range capabilities enable cleaved fiber analysis, showing both the cleaved end and jumper end (if one is used) return loss and location. *Figure 11* shows the RL as a function of position of a 5 meter jumper with FC/APC connectors on either end.

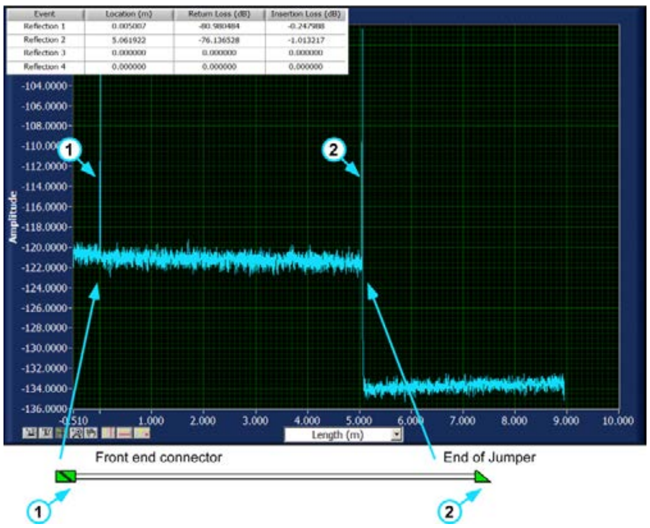


Figure 11. Illustration of the Rayleigh Scatter versus position of a jumper with a angle polished connector

Figure 12 shows the RL versus position of a 0.5636 meter fiber with a cleaved end attached to the jumper via a bulkhead after ~10 seconds of averaging (100 averages). Both the cleaved end and FC/APC jumper peak can clearly be seen. Due to the high RL of the cleaved surface, spatially symmetric side lobes about the cleaved end emerge from the noise floor. This effect is expected and is a product of the measurement method.

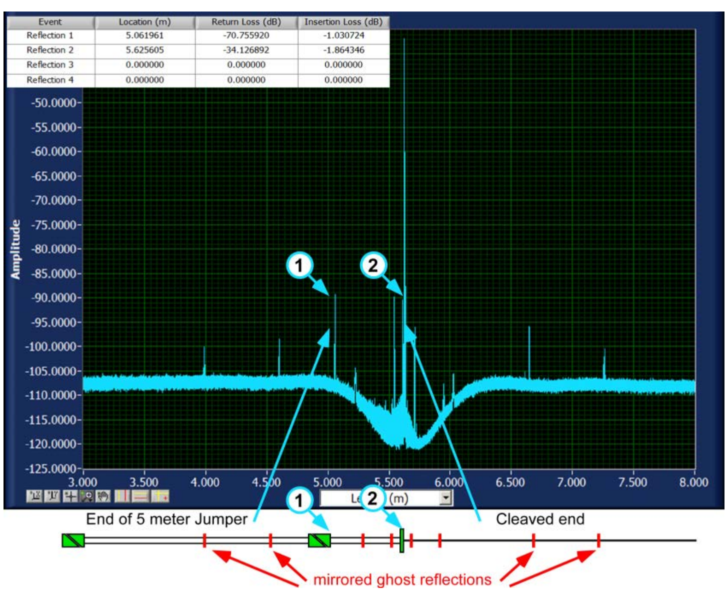


Figure 12 A close-up of Rayleigh Scatter versus position of a jumper with a cleaved end

b) Attenuator in Optical Path

An optical attenuator (provided with the system) can be used to improve system performance during cleaved fiber analysis. *Figure 13* shows the RL as a function of position of a 10 dB attenuator attached to the end of a 5 meter jumper. The event table shows the reflection events that correspond to the front and back faces of the attenuator. The attenuation can be detected as a linear spatial decay between points “1” and “2”.

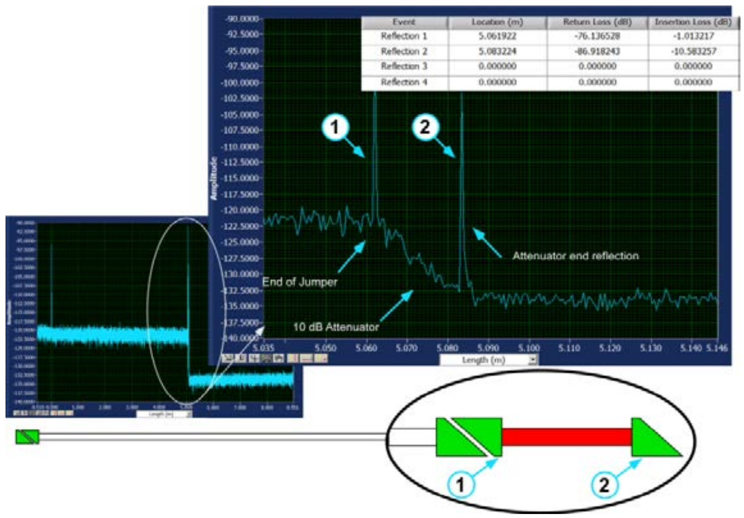


Figure 13 The Rayleigh scatter of a versus position of a 10 dB attenuator attached to an optical jumper

Figure 14 shows the RL versus position of the cleaved fiber attached to the attenuator after **~1 second** of averaging (10 averages). The end reflection of the jumper, attenuator and the cleaved fiber are clearly visible. The spatially symmetric side lobes about the cleaved end are still evident but are reduced in number and in magnitude. Subtracting the location value between the cleaved end and the attenuator, we find the jumper length to be 0.5636 meters. Note that the 3 largest peaks in the measurement are the cleaved end, jumper end and attenuator end.

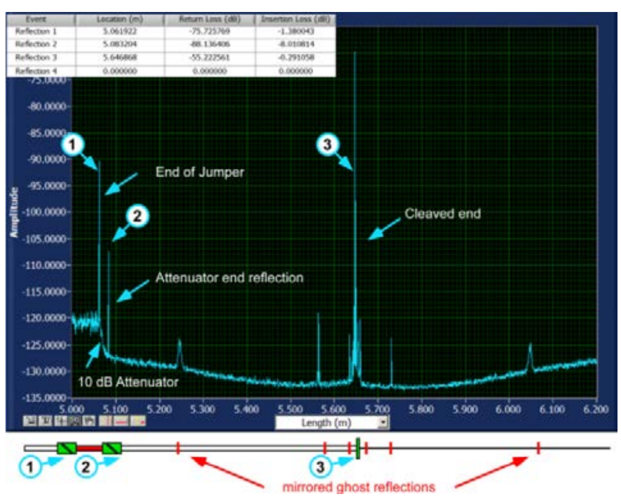


Figure 14 The Rayleigh scatter of a versus position of a cleaved fiber attached to 10 dB attenuator attached to an optical jumper

c) Suggested Process

The suggested process for making cleaved fiber length measurements in a production environment would be the following:

Connect and measure the optical jumper that will be used to offset the cleaved fiber from the front panel of the instrument. The jumper length will be reported in the event table as shown in *Figure 15* below.

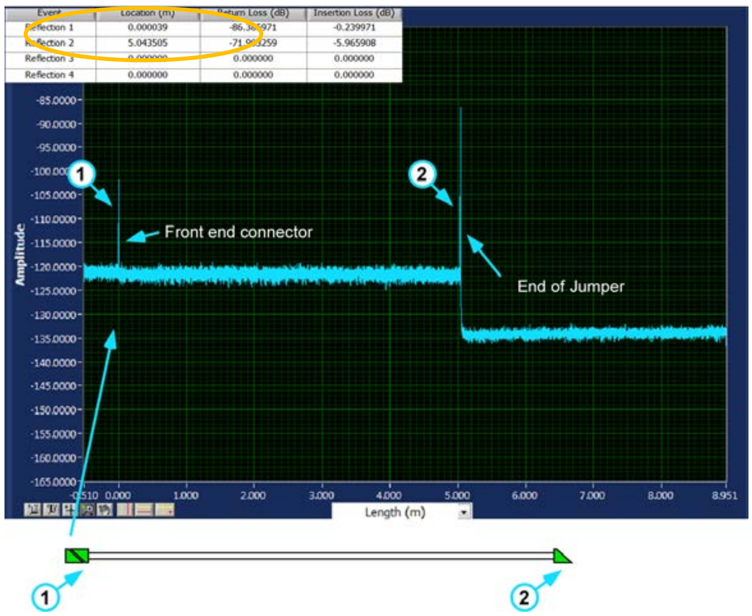


Figure 15. Test jumper with an FC/APC end termination

Record the jumper length in the zero length value located in the configuration dialog which can be found under the Tools menu as illustrated in Figure 16 below.

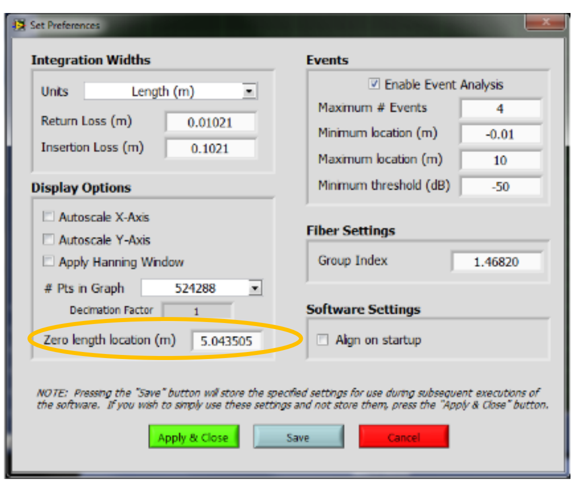


Figure 16 Preferences menu where user can set the "zero length location"

The table and graph will be reset to reflect the starting position identified as illustrated in *Figure 17*. In this example the jumper length, which would now correspond to the new start point, would be 5.043 meters.

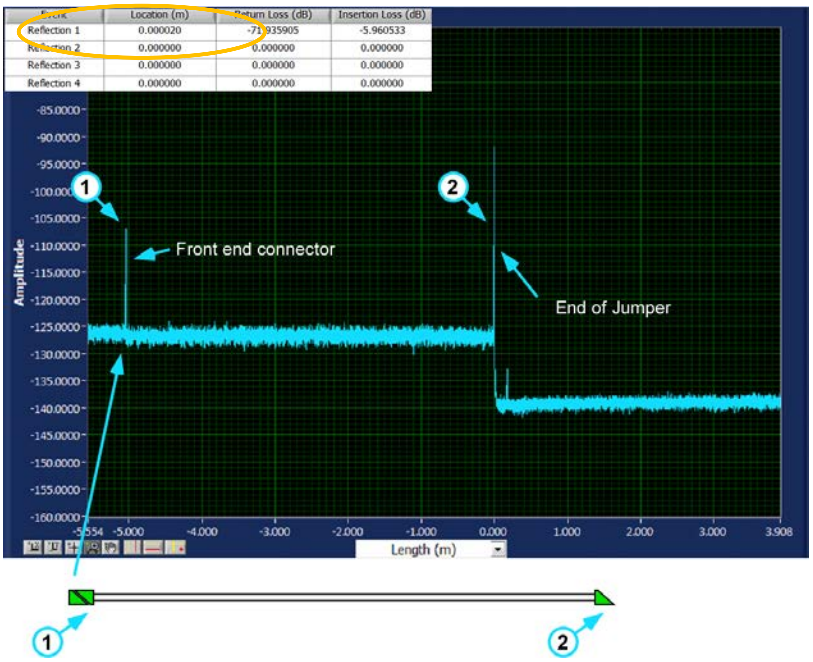


Figure 17. Illustration of the reseting of the "zero length" location

Next, in the user configuration menu, adjust the minimum threshold (dB) to >50 dB as illustrated *Figure 18*.

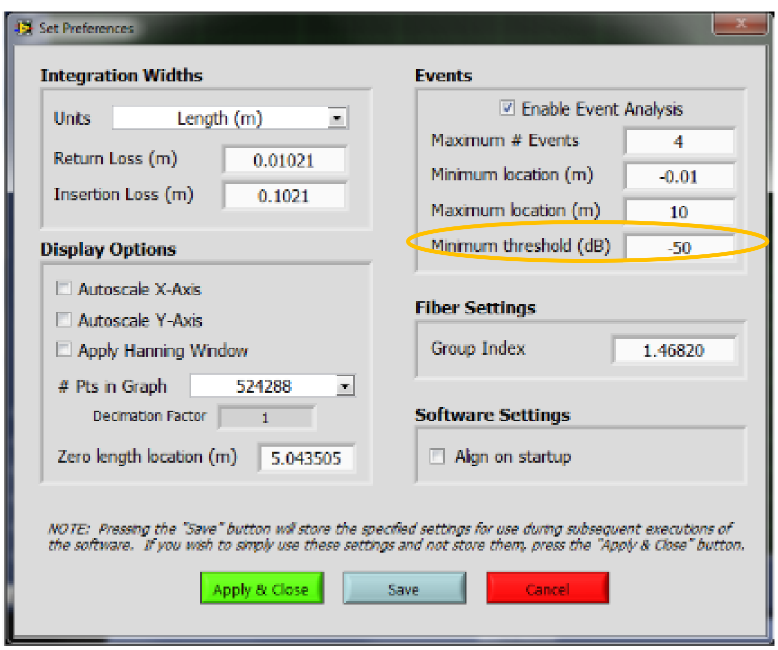


Figure 18 Preference menu configuration

Figure 19 illustrates the results obtained using the outlined procedure. The location value in the event table shows a length value of 0.556 meters.

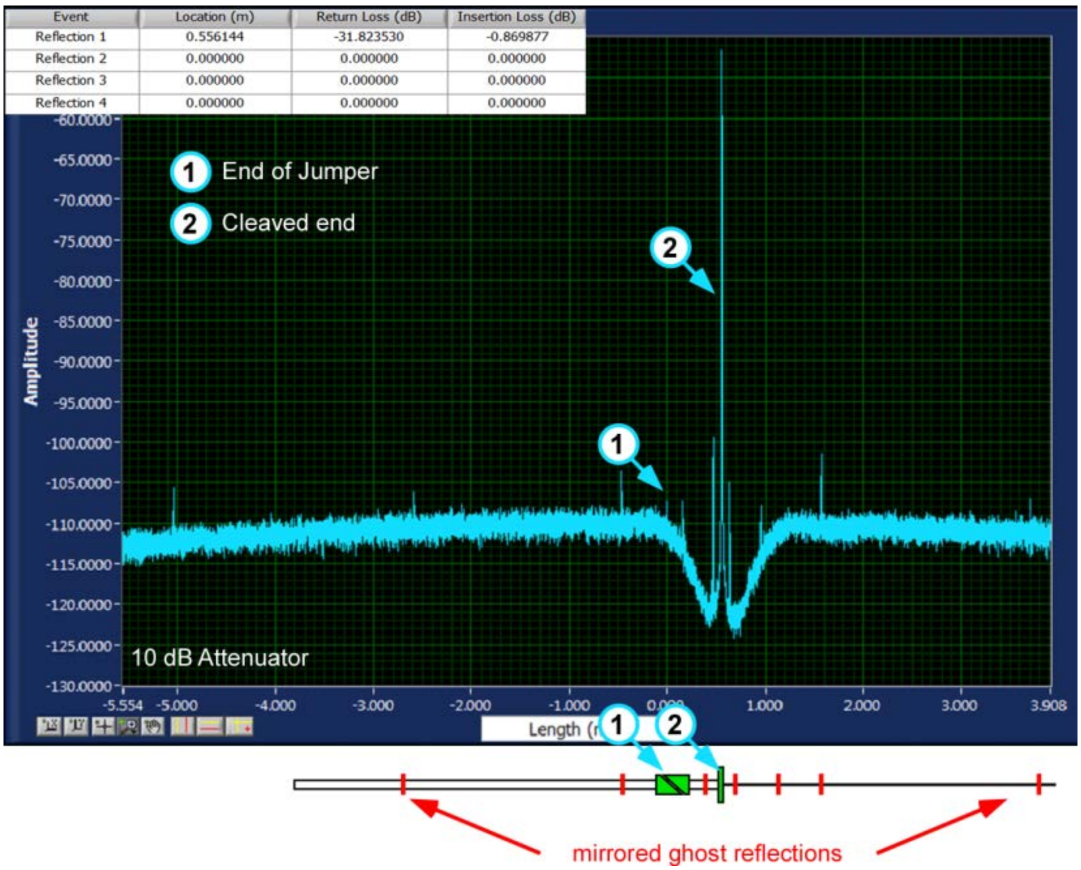


Figure 19. Reflection as a function of position of a cleaved jumper illustrating the capability of length determination using the procedure discussed.

DEFINITIONS

The following section describes terms used to define various parameters specified in the system performance table. The section also includes information that would help the end user better understand and operate the Luna **OBR 5T-50**.

1. Maximum Device Length

The longest length at which a device attached to the instrument can be measured as illustrated in *Figure 20* below. The system defined maximum device length is 8.5 meters.

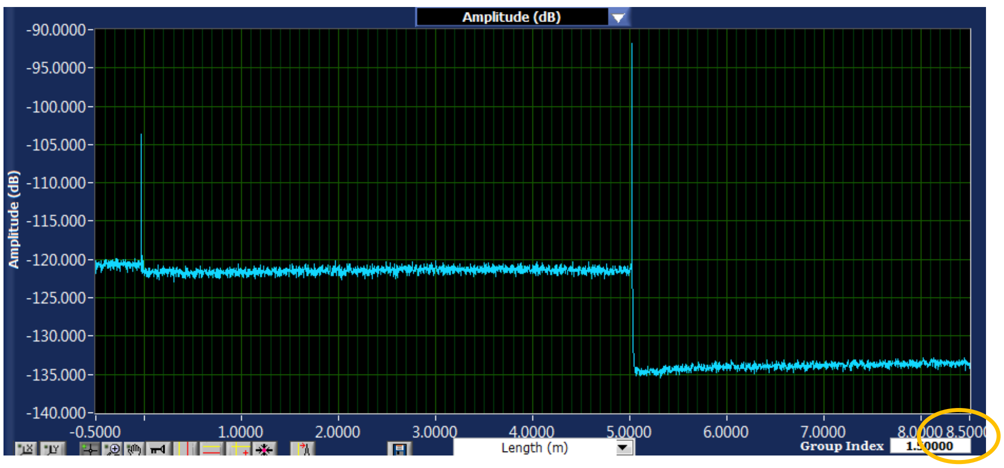


Figure 20. Ilustration of a the device length of the OBR 5T-50

2. Two Point Spatial Resolution

The spatial distance between two adjacent points in the Rayleigh scatter amplitude data array as illustrated in *Figure 21*. The system defined 2-point spatial resolution is 20µm.

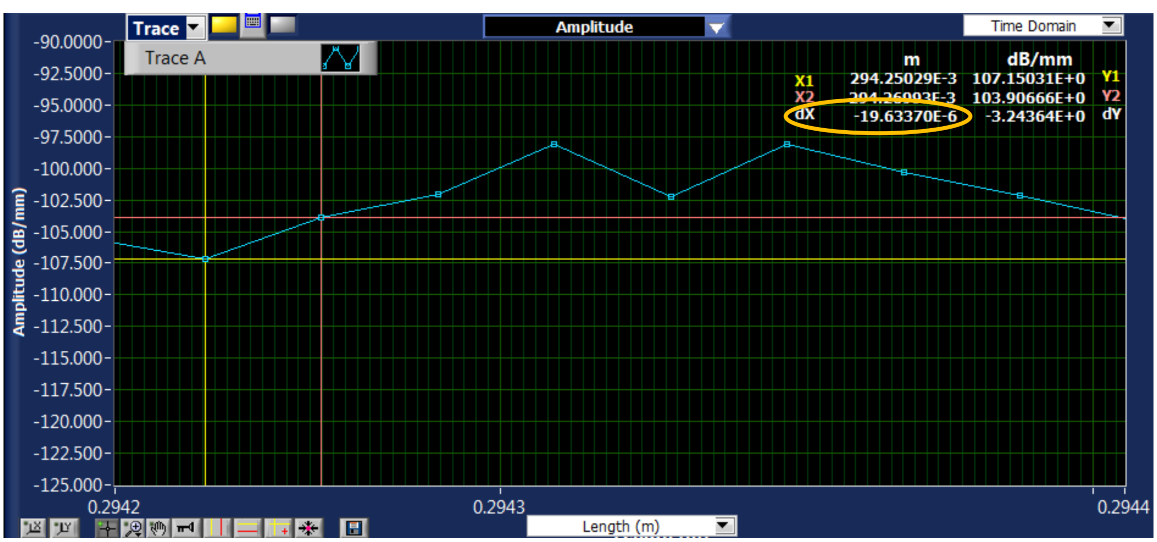


Figure 21. Illustration of the two point resolution of the OBR 5T-50

3. Integrated Return Loss

Optical return loss is the loss of optical signal power usually due to a discontinuity in an optical fiber or minor changes in the index of refraction along the optical path.

a) Dynamic Range

This is defined as the difference between the largest and smallest peak that can be simultaneously measured.

b) Return Loss Dynamic Range

The difference between the return loss of a highly reflective peak and the maximum value of system noise level neglecting spurious events such as side lobes. *Figure 22* is a measurement of a 5 meter optical fiber jumper attached to a ~0.5 meter fiber with a cleaved end. The fiber cleave produces a high return loss event generating side lobes and migrating the system noise floor to ~108dB. The curve was generated by averaging 100 scans at 10 Hz. The red and yellow cursors show the maximum peak height and system noise floor, thus demonstrating the Return Loss Dynamic Range. In this example we measure a range of 68.9 dB.

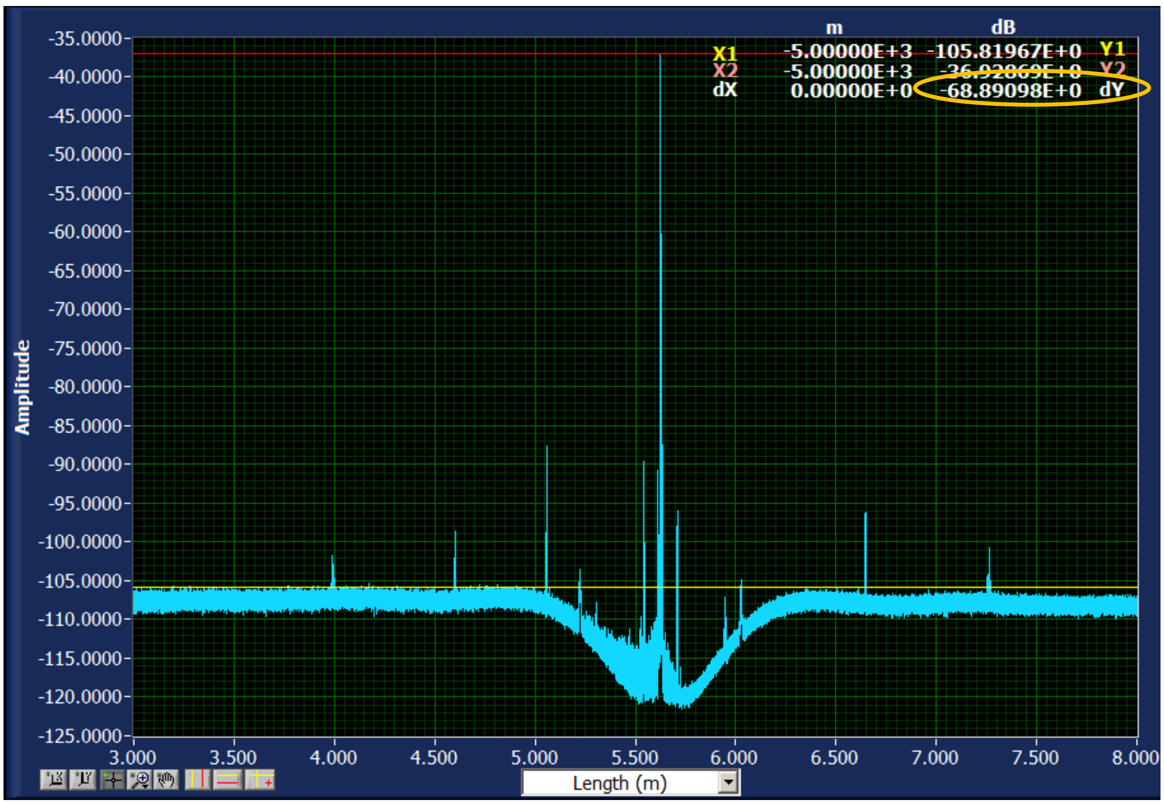


Figure 22. Illustration of the Return Loss dynamic range

c) Total Range

The range between the strongest and weakest reflectivity that can be measured. The lowest reflective event would be peaks right above the noise floor, depicted by the red, horizontal cursor in *Figure 23*. By defining the strongest measureable reflection as can be seen by the **OBR 5T-50** to be ~ -14 dB, the system range would be greater than 110 dB.

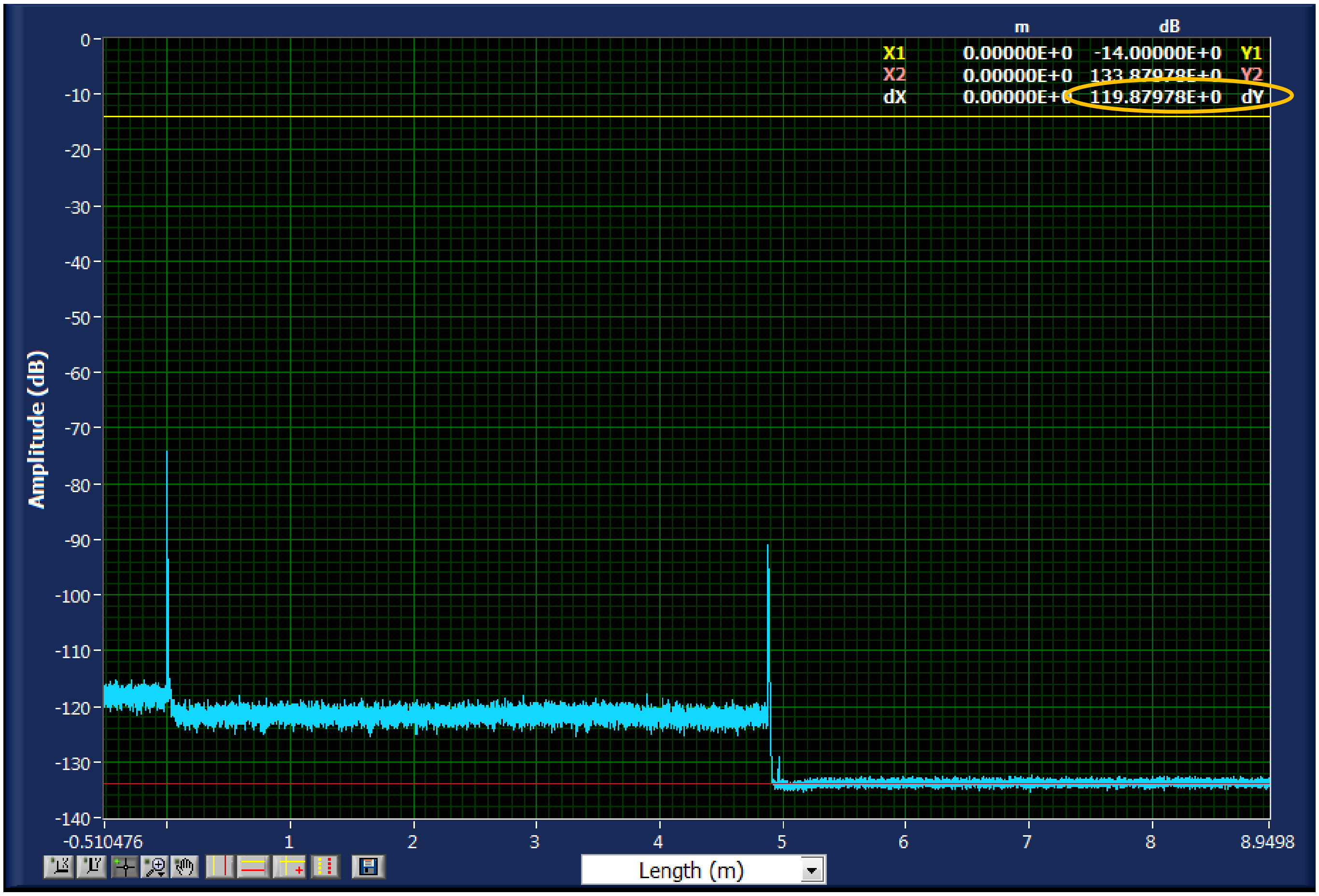


Figure 23. Illustration of the Return Loss total range

d) Sensitivity

The smallest reflectivity that can be measured by the device. This would be right above the system noise floor. Figure 24 shows a jumper measurement using the **OBR 5T-50**. Here we see a system sensitivity of -130 dB. It is worth noting that reflectometers available in the market have a common Return Loss dynamic range and sensitivity of ~ -80 dB. The events above the highlighted region are an illustration of what would be seen with such instruments.

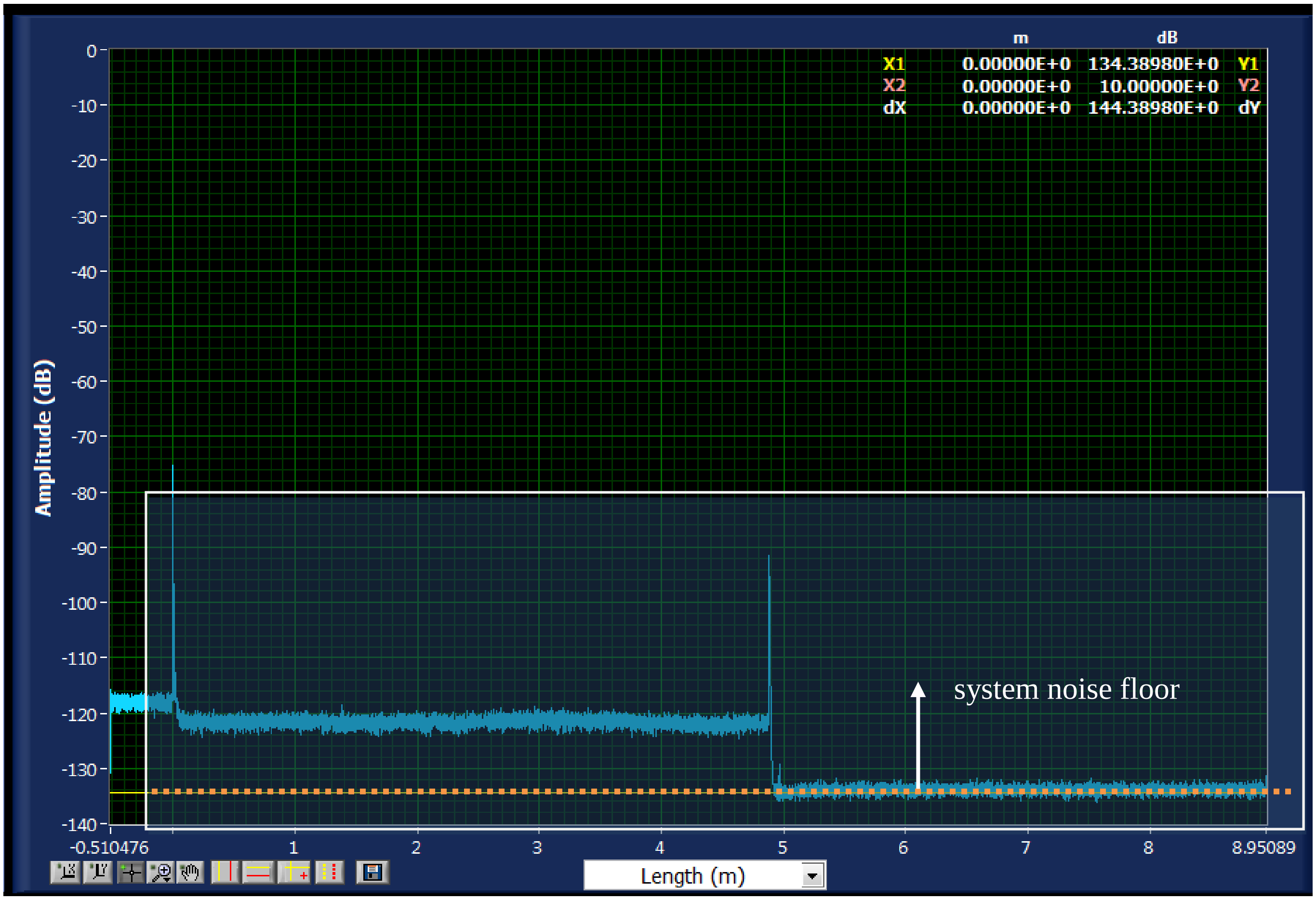


Figure 24 Illustration of the Return Loss sensitivity

e) Resolution

The smallest vertical distance between the mean level of Rayleigh scatter on either side of a loss event as illustrated in *Figure 25*. The event below is induced due to a bend. The mean level of the Rayleigh Scatter is depicted by the red and yellow horizontal cursors.

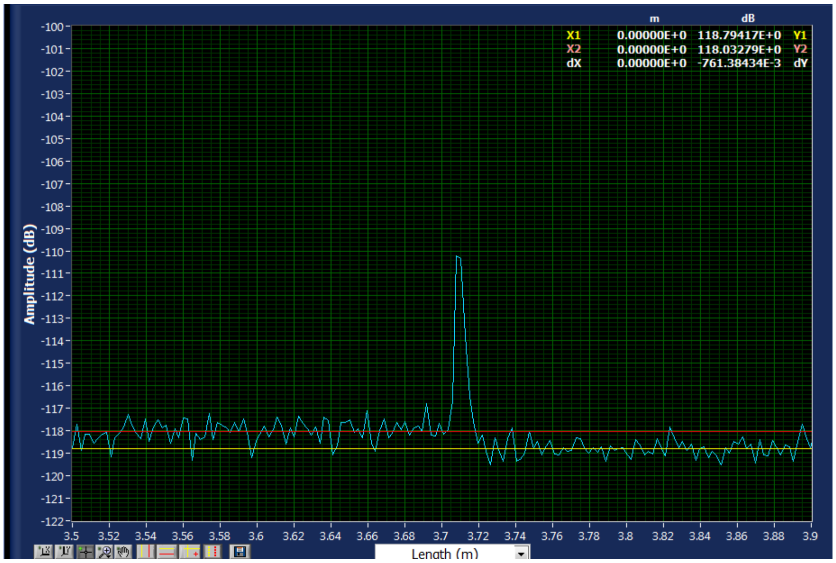


Figure 25. Illustration of Return Loss resolution

4. Integrated Insertion Loss

The **OBR 5T-50** measures the insertion loss event by integrating the Rayleigh scatter level on either side of a loss event, subtracting the two values and dividing by two to represent one-way loss as illustrated in *Figure 26* below.

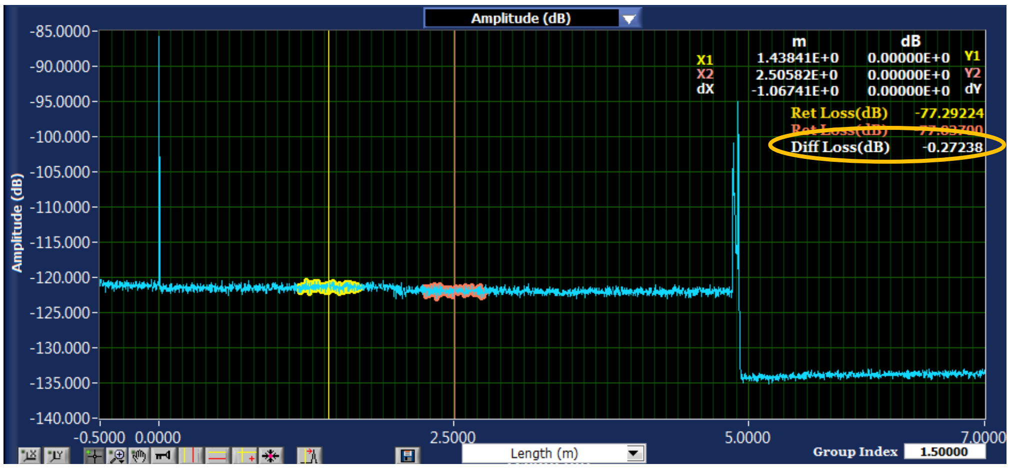


Figure 26. Illustration of an Integrated Insertion Loss measurement

a) Resolution

The Insertion loss resolution is defined as the smallest resolvable change of insertion loss a system is capable of detecting. *Figure 27* illustrates a series of acquisitions of a various fusion splices with varying losses. The Luna **OBR 5T-50** is defined to have an insertion loss resolution of ±0.5 dB.

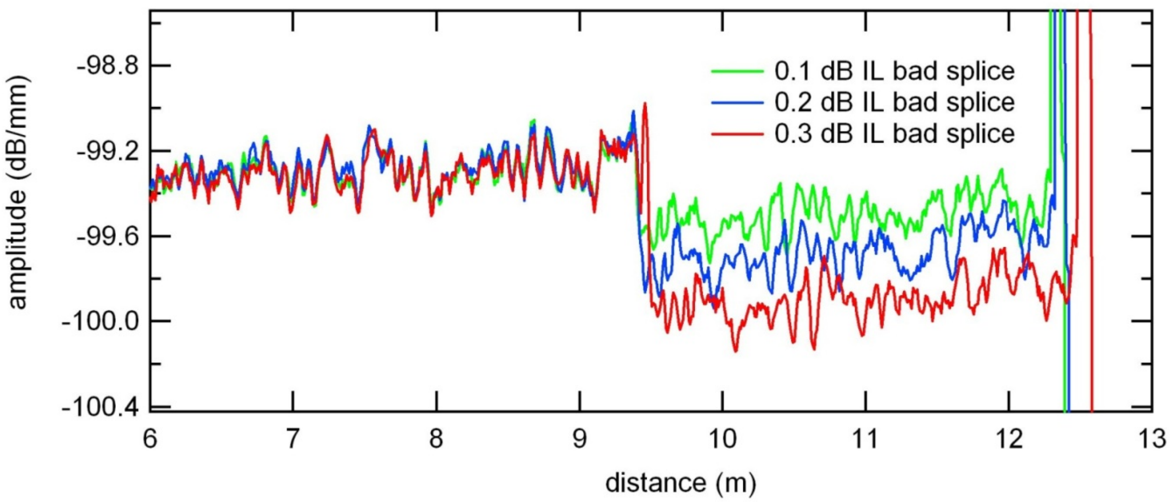


Figure 27. Illustration of Integrated Insertion Loss resolution

b) Accuracy

The Insertion loss accuracy is defined as how close the reflectivity or return loss measurement is to the actual physical value. *Figure 28* shows an example of a comparison between a calibrated two-way, insertion loss measurement technique and a Backscatter Reflectometer on a 9 port switch. The Luna **OBR 5T-50** is defined to have an insertion loss accuracy of ±0.5 dB.

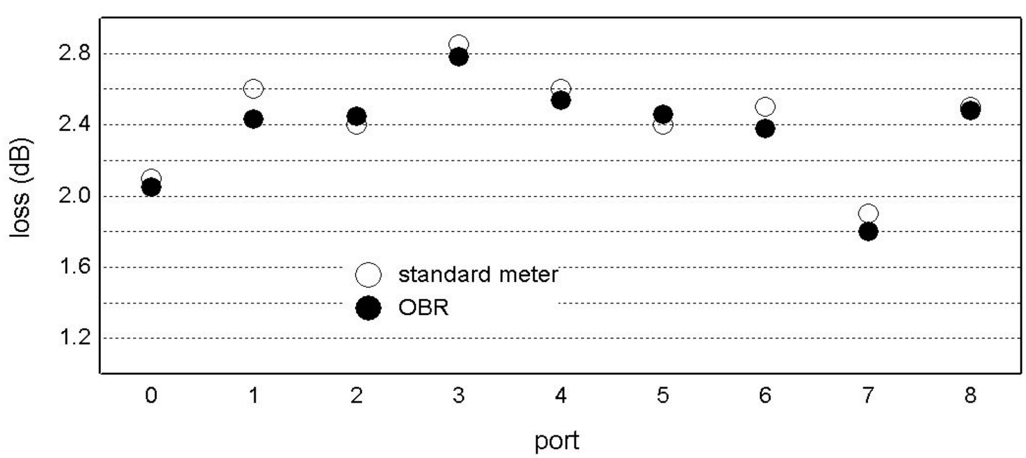


Figure 28. Illustration of Integrated Insertion Loss accuracy