

Skew and Strain Measurements Using the Optical Backscatter Reflectometer to Support TIA FOTP 455038

Introduction

Luna Technologies' Optical Backscatter Reflectometer Series 4600 (herein referred to as 'OBR') has the ability to make long distance length measurements of up to 2 kilometers within the standard measurement platform. Below is a step-by-step procedure to guide the user in determining skew and strain.

Measurement Procedure

Initial Setup

The OBR and accompanying PC will need to be powered up and running. Ensure that the USB 2.0 data transfer cable from the OBR is plugged into the computer. The fiber(s) under investigation will need to be spliced with an APC connector and mated to the front panel of the instrument as illustrated in Figure 1 below. For further reference on system setup, please review Chapter 2 of the OBR User Guide.

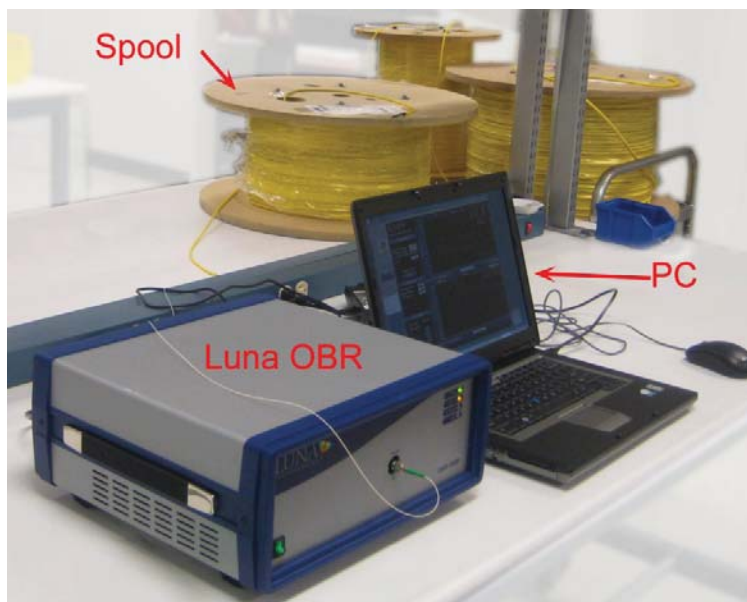


Figure 1: Luna Technologies' OBR interrogating an optical lead in a ~750m fiber spool

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Length Measurement Procedure

a) To launch the application click on “Start->Programs->OBR vX.X.X->OBR vX.X.X.”

b) **Optional:**

The wavelength range, and hence, the two-point resolution may be changed by navigating to ‘Options->Instrument Configuration’.

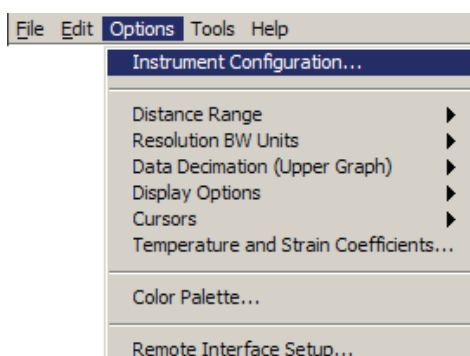


Figure 2: Navigation to instrument configuration to change wavelength range

On the “Instrument Configuration” panel, the user may change the 2-point resolution by toggling the lower menu (labeled ‘A’ in Figure 3 below). The measurement resolution for each selection is displayed on the right side of the panel.

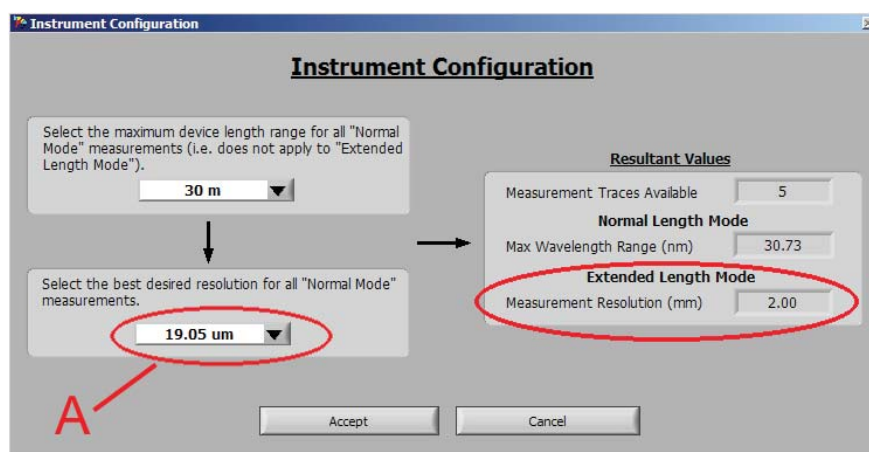


Figure 3: Normal Mode selection within Instrument Configuration panel

After clicking ‘Accept’, the system will re-configure. To do this the application will have to shut down and will prompt the user accordingly. After restarting the software, proceed to the next step and the system will be configured to work at the selected resolution.

- c) The OBR graphical user interface (GUI) is divided into two regions. As shown in Figure 4 below, the settings pallet located on the left facilitates user input for “*System Control*”, “*Data Processing*” and “*Display Options*”. The second region is the graphical display to view acquired data. When data is imported, it is displayed in the top graph. The default display settings show a decimated form of the data to give the user a global perspective of the entire scan length. A high resolution subset of the scan can be highlighted and displayed in the bottom graph. Each graph has an array of tools available to aid in visual selection and interpretation of the data (see label ‘A’, Figure 4). The length can be displayed in ‘Meters’, ‘Feet’ or ‘Nanoseconds’ by toggling the pull-down menu below each graph (see label ‘B’, Figure 4). In order for the proper lengths (in Meters or Feet) to be computed, the appropriate “*Group Index*” (Index of Refraction) as provided by the manufacturer must be entered in the field labeled ‘C’ in Figure 4.

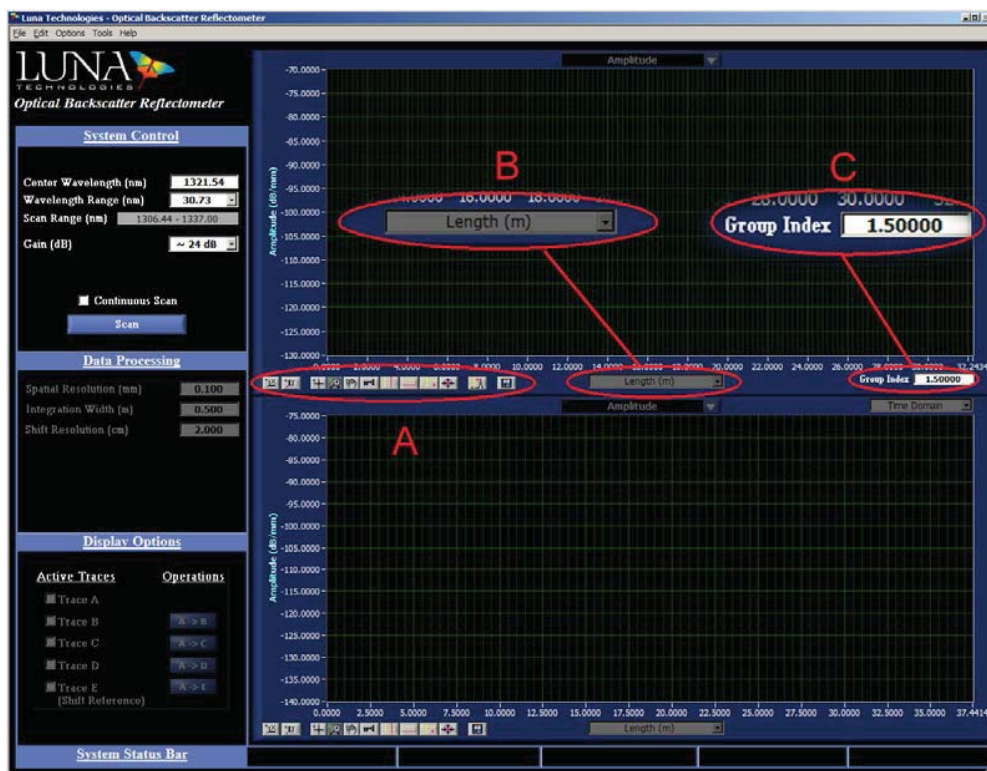


Figure 4: Labeled screenshot of OBR Analysis Software with plot tools (A), measurement length dropdown (B), and index of refraction data field (C)

- d) In order to make measurements of networks longer than 70 m, the instrument will need to be configured to the ‘*Extended Range*’ mode of operation. To accomplish this, on the tool bar navigate to: ‘*Options->Distance Range-> Extended*’ (see Figure 5 below).

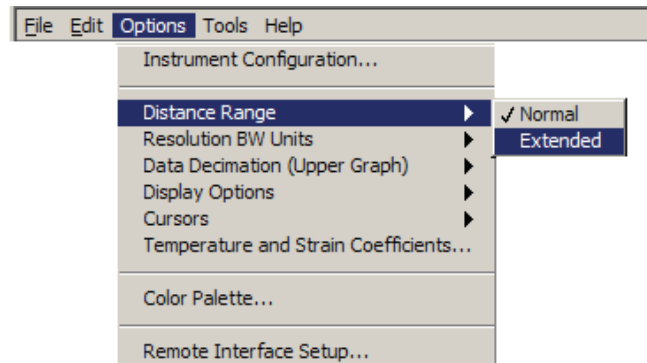


Figure 5: Navigation to normal/extended measurement settings

- e) The wavelength range is set in the “System Control” panel on the left side of the screen. The value may be either 0.4 or 0.8 nm. The longer wavelength range doubles the 2-point resolution and hence, doubles the computational time. When in extended range mode, a new item appears on the “System Control” menu labeled ‘DUT Length (m)’ where DUT is an abbreviation for Device Under Test. This control should be set to the length of the fiber being measured.

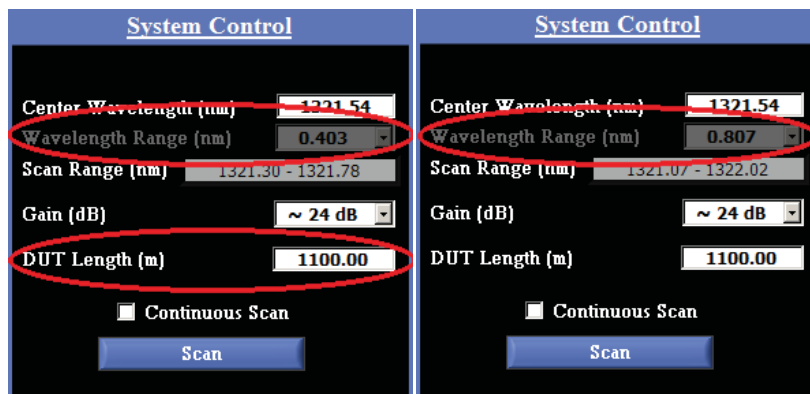


Figure 6: System Control panel showing wavelength range options of 0.403nm and 0.807nm as well as DUT Length field

- f) Press the ‘Scan’ button to perform a measurement.
- g) After a ~30 sec acquisition and processing time, a trace characterizing the DUT will appear on the top graph. The end of the DUT length is characterized by a sharp rise in reflection due to the termination of the fiber, followed by a drop to the noise floor, as is illustrated below in Figure 7.

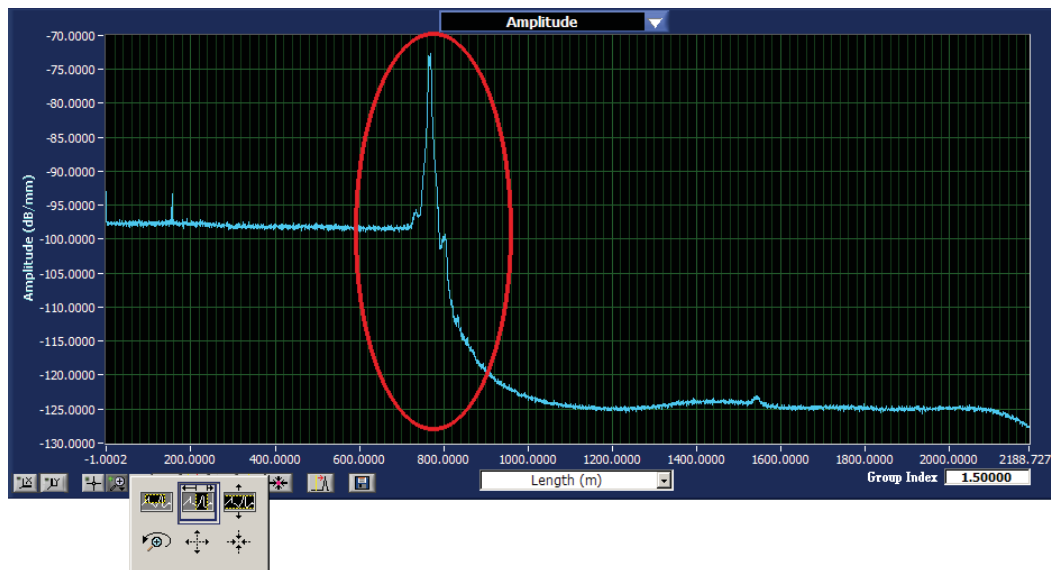


Figure 7: Amplitude plot showing sharp rise and fall to noise floor due to fiber termination

- h) In order to refine the DUT length measurement to a more precise value ($\pm 0.5 \text{ m}$ at $<1\text{KM}$), the user can find a more precise location for the end reflection peak, re-enter the new DUT length, and scan again. This serves to narrow the width of the measured reflection peak and leads to a more accurate length measurement. The sub-steps below detail the procedure to accurately measure the DUT length.
- i. On the top graph, activate the vertical cursors (labeled 'A', Figure 8). Using one of the cursors, horizontally shift it to point that is approximately at the center of the end reflection peak reflection as seen below. A value of the location will then be displayed on the upper-right hand corner of the top graph. Copy the appropriate, color-coded value (labeled 'B', Figure 8) and paste it to the "DUT Length" field on the "System Control" menu (labeled 'C', Figure 8).

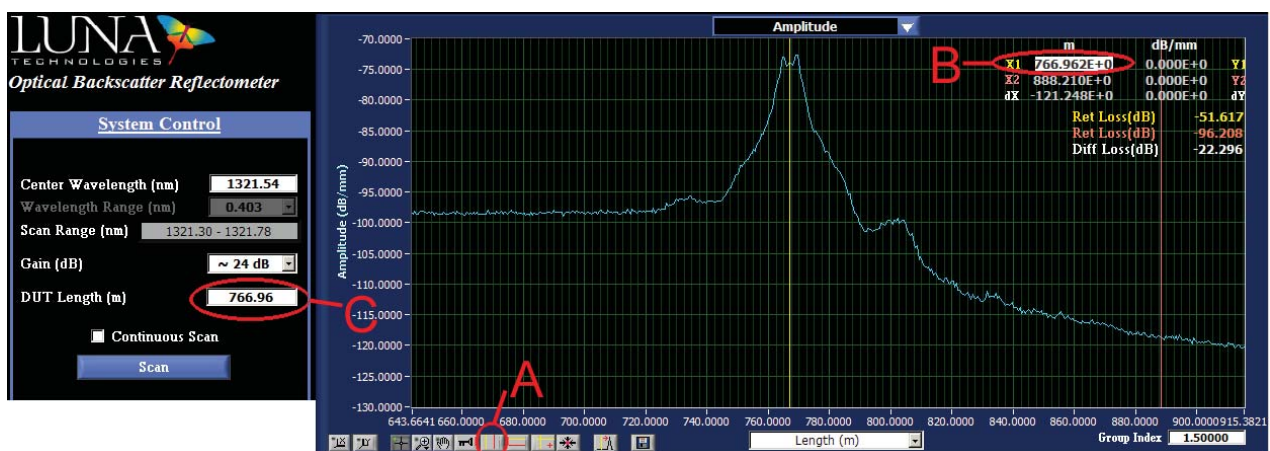


Figure 8: Top graph shown with activated vertical cursors. Vertical cursor toggle (A), vertical cursor positions (B), and DUT length (C)

ii. Acquire a new scan by pressing the “Scan” button. Notice the previous, broad peak becomes more defined.

iii. In the “Integration Window” field (labeled ‘A’, Figure 9), enter a length such that the highlighted region encompasses the peak.

iv. Click on the “Find Peak” button (labeled ‘B’, in Figure 9). This will center the integration window on the peak of interest. An approximate value of the peak location may be obtained from the color-coded menu on the right, top corner of the upper graph.

v. A more accurate measurement may be obtained by moving the highlighted data to the lower graph, where the data subset will be displayed at maximum resolution. To do this, click on the “Calculate” button (labeled ‘C’, Figure 9).

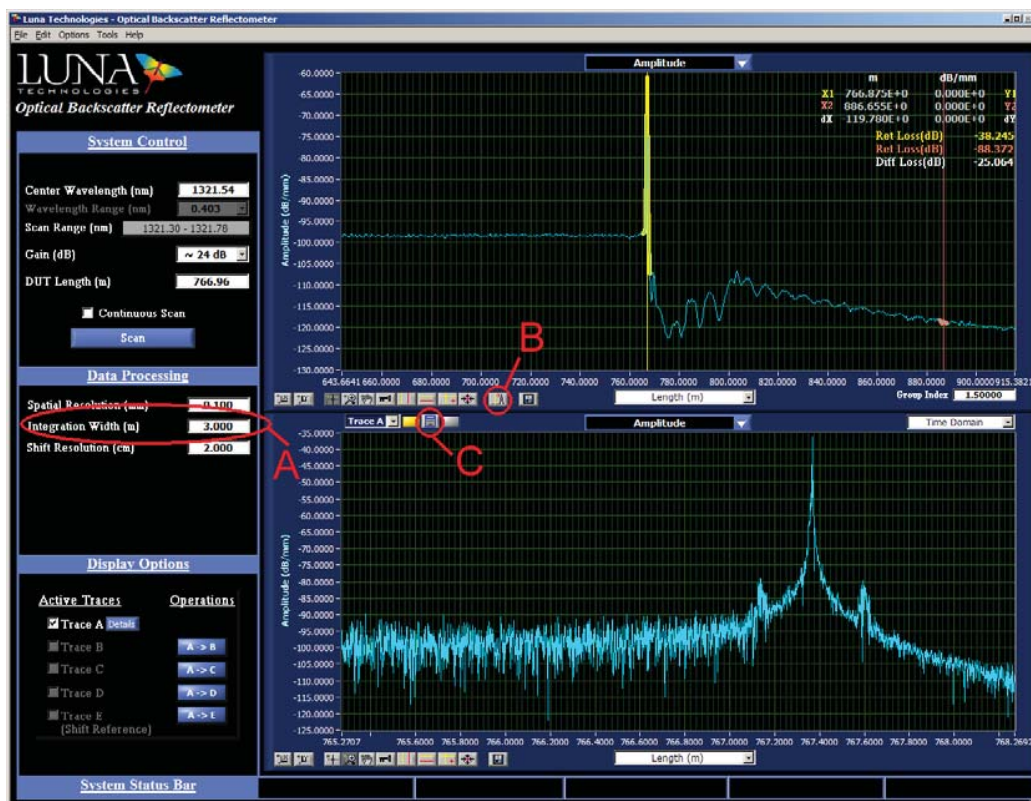


Figure 9: OBR analysis software showing integration width entry field (A), find peak feature (B), and calculate lower graph (C)

vi. Using the zoom tool, (magnifying glass icon located at bottom left of the lower graph) zoom in further into the end reflection as shown in Figure 10 below.

vii. To obtain the peak location, activate the 'Cross-hairs' (labeled 'A', Figure 10) and move the cursor until it snaps on to the highest value on the peak.

viii. Record the color-coded DUT length on the upper right hand corner of the lower graph as the final value of interest.

ix. To change the units to "Meters", "Feet" or "Nanoseconds" toggle the pull-down menu (labeled 'C', Figure 10) to the appropriate unit of choice.

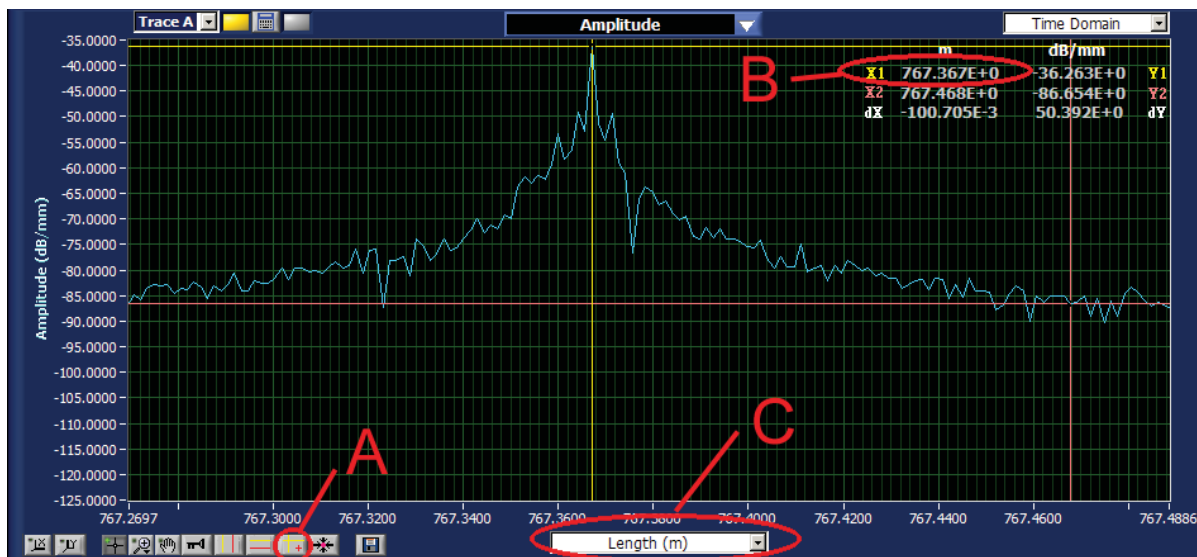


Figure 10: Lower graph and tools showing cross-hairs (A), cross-hair positions (B), and x-axis unit drop down (C)

Note: The length in nano-seconds (also known as the time of flight (TOF)), is the time it takes the light to go to the end of the fiber and come back to the OBR. Therefore, it is necessary to divide this value by 2 to get the one-way TOF to the end of the fiber.

Skew and Strain Calculation

To determine skew measurements, TOF measurement for all the fibers within the cable must be repeated. The skew is then determined by:

$$Sk_i = \frac{\Delta t_i - \Delta t_{\min}}{\frac{c}{N \cdot M} \cdot \sum_{i=1}^M \Delta t_i} = \frac{\Delta t_i - \Delta t_{\min}}{L_{avg}} \quad (1)$$

Where

Sk_i = The skew for fiber ‘i’

Δt_i = The TOF to the end of the fiber. (½ the TOF as measured by the OBR) [nanoseconds]

Δt_{\min} = The minimum TOF measured of the fibers in the cable

c = The speed of light (299,792,458 m/s)

N = The Effective fiber group index as specified by manufacturer

M = The number of fibers

L_{avg} = The average length of the cable (Gauge length), May use manufacturer specified length [meters]

To measure the distributed strain according to TIA-455-38, the TOF will need to be made according to the procedure stated above at the pre-determined strain states. The strain is then determined by¹

$$\epsilon_f = (t_{str} - t_{ref}) \cdot \left(\frac{c}{L \cdot N} \right) \cdot \left(\frac{1}{k} \right) \quad (2)$$

Where

t_{str} = Measured delay time (strained) [seconds]

t_{ref} = Measured delay time (reference) [seconds]

L = Specimen gauge length [meters]

N = is the Effective fiber group index as specified by manufacturer

k = Stress Optic Correction factor²

¹ Equation obtained from the “Measurement of Fiber Strain in Cables Under Tensile Load”, TIA-455-38, TIA Document, pg 10

² See ref [1] section 5.1 for more information.



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