Using the OVA's Compression Option to Narrow Impulse Responses Broadened by Dispersion

Contents

1 Introduction

The *Pulse Compression* feature of Luna's Optical Vector Analyzer (OVA) software can be used to compress the impulse response of a device under test (DUT) by mathematically removing dispersion effects from the measured device response. Removing the effects of dispersion can narrow and sharpen features in the time-delay domain that are broadened by dispersion. It can also enable highly dispersive devices, such as some dispersion compensation gratings or modules, to be characterized by the OVA. Without pulse compression, the OVA optical network accommodates impulse response durations of 6 ns or less if the DUT is measured in transmission and half or less of that value if it is measured in reflection.

2 Dispersion

Dispersion causes different wavelengths to travel at different velocities in a medium. [1] One consequence of this is that pulses broaden, and can change shape, as they propagate. The device response measured by the OVA includes both amplitude and phase data. Dispersion effects alter the phase, rather than the amplitude of the device response. Dispersion occurs because the index of refraction of the medium, n(ω), is dependent on optical frequency, ω (wavelength, λ). Because the phase of the propagating light is directly proportional to the refractive index, the phase, ϕ, is also dependent on frequency,

$$\phi(\omega) = \frac{\omega n(\omega)}{c} L \tag{1}$$

where L is the length of the medium, and c is the speed of light in vacuum.

It is common to express the frequency-dependent phase in terms of a Taylor series, where ω_o is a specific frequency of interest,

$$\phi(\omega) = \phi_o + \frac{d\phi}{d\omega} \cdot (\omega - \omega_o) + \frac{1}{2}\left(\frac{d^2\phi}{d\omega^2}\right) \cdot (\omega - \omega_o)^2 + \frac{1}{6}\left(\frac{d^3\phi}{d\omega^3}\right) \cdot (\omega - \omega_o)^3 + \cdots \tag{2a}$$

$$\phi(\omega) = \phi_o + \tau_g(\omega) \cdot (\omega - \omega_o) + \frac{CD(\omega)}{2} \cdot (\omega - \omega_o)^2 + \frac{TOD(\omega)}{6} \cdot (\omega - \omega_o)^3 + \cdots \tag{2b}$$

The zeroth-order term, ϕ_o, is a constant phase shift and does not affect dispersion. The first-order term contains the group delay, τ_g, which is calculated by computing the first derivative of the phase with respect to frequency. Changes in the group delay cause a shift in the time-domain device response but do not affect dispersion. Terms of second-order and higher do affect dispersion, and the impulse response compression feature of the OVA allows the user to mathematically remove dispersion effects related to the second and third order terms from the measured device response.

The second order term contains the group velocity dispersion, or chromatic dispersion (CD), which is frequently described in the literature by a related parameter known as the dispersion coefficient. It describes the broadening of the pulse due to dispersion. The third order term (TOD), is the slope of the dispersion coefficient, and, when its value is non-negligible, dispersion not only broadens but also alters the shape of the pulse. (e.g. a pulse with an initially Gaussian shape would not keep its Gaussian pulse shape as it propagates through the optical network.)

3 Pulse Compression Implemented by the OVA: An Overview

Finding the optical frequency-domain transfer function of the device requires first finding the time-domain impulse response. [2] [3] Fourier transform techniques are used to convert between the time-domain impulse response and the frequency-domain transfer function of the DUT. The device response measured by the OVA is processed to yield four individual time-domain impulse response elements. The impulse response elements are separated from one another in the time-domain by delay lengths determined by the geometry of the OVA's optical measurement network. The OVA uses windowing techniques to select and isolate the individual elements. After transforming each time-domain element into the frequency domain, these four elements collectively compose the transfer function of the device.

The OVA optical network accommodates impulse response durations of 6 ns or less if the DUT is measured in transmission and half or less of that value if it is measured in reflection. This separation time is sufficient for most fiber optic components, as typical impulse response durations do not exceed 1 ns. However, highly dispersive devices, such as some dispersion compensating modules, have longer impulse response durations. If the impulse response of the DUT is longer than the maximum temporal separation accommodated by the OVA, the individual elements of the transfer function overlap in the time domain and cannot be separated. This corrupts the computed transfer function of the DUT. Because of the limit on the maximum impulse response duration, when the OVA is used to characterize highly dispersive devices it is necessary to compress the impulse response of the device.

Impulse response compression can also be used to mitigate dispersion effects that obscure device features of interest. Even when the time-domain impulse response of the device falls within the limit defined by the OVA, the dispersion accumulated by signals propagating through the device may be unacceptably high. This may be the case when it is of interest to directly compare two similar events which occur at different positions in the device, such as when one occurs near the proximal end and the other near the distal end of the DUT. Dispersion effects would differently affect the evolution of light from the two and complicate the comparison and characterization process.

Impulse response compression is performed on the measured device response data before the Jones matrix (transfer function) of the DUT is computed. The pulse compression feature computes a phase correction term from user-input values of the average group velocity dispersion, d_a, and the slope of the dispersion coefficient, d_s. One approach for obtaining these values is to compute them from mathematical fits made to the group delay data of the device. Referencing Equation (2), if the phase of the device is expressed as, ϕ_{poly}, where the coefficients a, b, d_a, d_s, and f are constants,

$$\phi_{poly}(\lambda) = a + b \cdot (\lambda - \lambda_o) + \frac{1}{2} d_a \cdot (\lambda - \lambda_o)^2 + \frac{1}{6} d_s \cdot (\lambda - \lambda_o)^3 + \frac{1}{24} f \cdot (\lambda - \lambda_o)^4 + \cdots \qquad (3)$$

then the derivative, which is the group delay, GD_{poly}, is

$$GD_{poly}(\lambda) = const + d_a \cdot (\lambda) + \frac{1}{2} d_s \cdot (\lambda - \lambda_o)^2 + \frac{1}{6} f \cdot (\lambda - \lambda_o)^3 + \cdots \qquad (4)$$

The slope of the linear fit to GD_{poly} is d_a, and the second order fit to $\left\{GD_{poly}(\lambda) - d_a \cdot (\lambda)\right\}$ is d_s /2. (Note: it is necessary to multiply the second order fit coefficient by two (2) to obtain d_s.) Impulse response compression is implemented by subtracting the constant values d_a and d_s from the appropriate elements in the phase of the device response measured by the OVA to give a residual phase response, ϕ_r,

$$\phi_r(\lambda) = \phi_o + \tau_g(\lambda) \cdot (\lambda - \lambda_o) + \frac{CD(\lambda) - d_a}{2} \cdot (\lambda - \lambda_o)^2 + \frac{TOD(\lambda) - d_s}{6} \cdot (\lambda - \lambda_o)^3 + \cdots \qquad (5)$$

When pulse compression is enabled, the chromatic dispersion calculated by the OVA, CD_{pc}, will be the actual chromatic dispersion, CD, less a correction term,

$$CD_{pc}(\lambda) = CD(\lambda) - \big(d_a + d_s \cdot (\lambda - \lambda_o)\big), \qquad (6)$$

and the calculated group delay, GD_{pc}, will be the actual group delay, GD, less an integrated correction term,

$$GD_{pc}(\lambda) = GD(\lambda) - \left(d_a \cdot \lambda + \tfrac{1}{2} d_s \cdot (\lambda - \lambda_o)^2\right). \tag{7}$$

If the transfer function computed using pulse compression is to be used for modelling purposes, it is necessary to expand the impulse responses to their original states. This can be done by multiplying each element of the Jones matrix by the complex conjugate of the phase correction term in the frequency domain.

Once enabled, impulse response compression is applied to all subsequently acquired measurements. Measurements that have been acquired previous to enabling pulse compression are not altered.

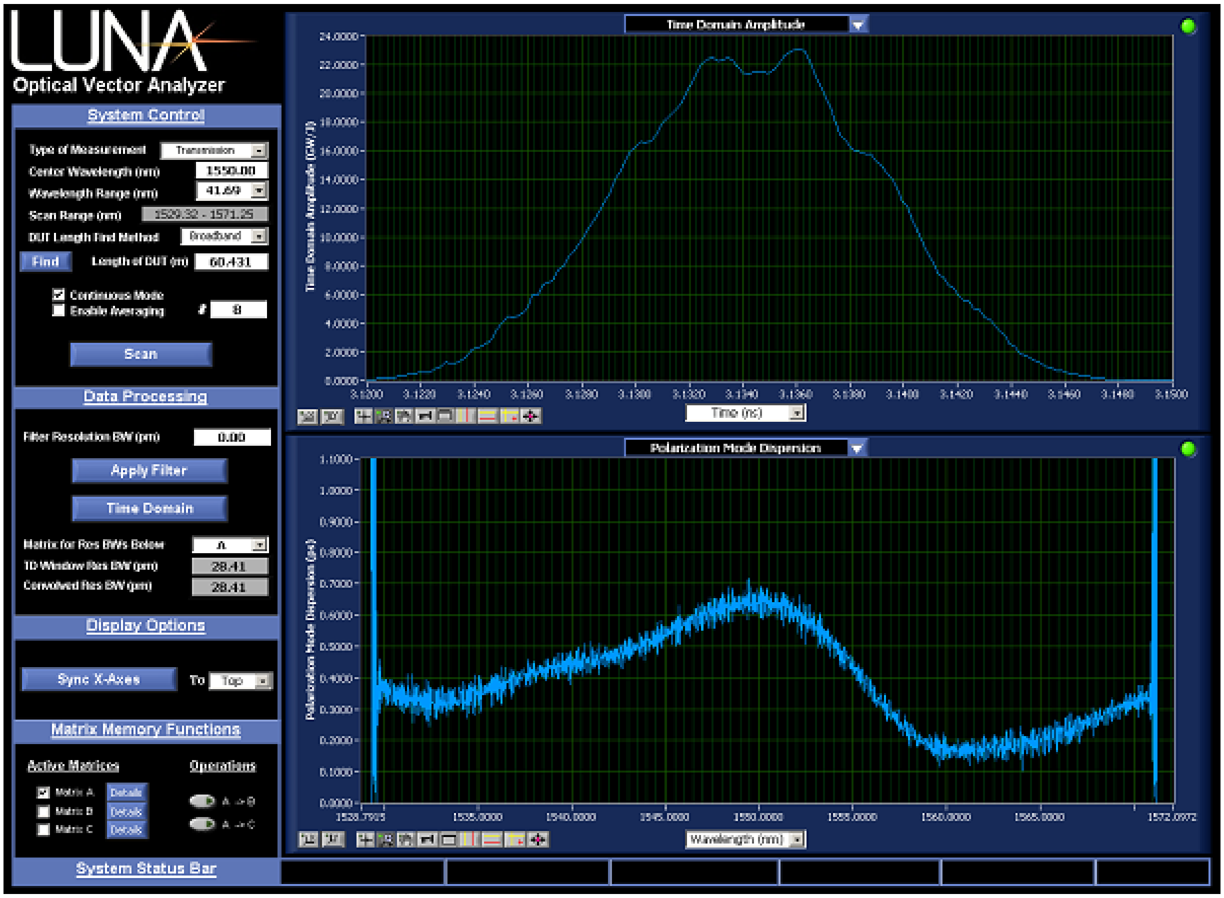
4 Using Impulse Response Compression to Sharpen DUT Features

When dispersion obscures the characteristics of a feature of interest in the time-delay domain, pulse compression can be used as a tool to remove either or both the average dispersion and the slope of the dispersion from the transfer function computed for the DUT. This section treats the case in which the impulse response duration of the DUT falls within the limits accommodated by the OVA, so that the transfer function of the device can be accurately computed by the OVA without using pulse compression. (The case when the impulse response duration of the DUT is wider than the extent permitted by the OVA is addressed in the next section.)

Implementation of pulse compression under these conditions is demonstrated using OVA transmission measurements taken of an approximately 60 m long length of low bend-loss singlemode optical fiber, which exhibits higher levels of dispersion than the standard singlemode optical fiber that is more common in telecommunications networks. In addition, although the fiber is not intended to exhibit birefringence, its custom over-coating results in the orthogonal polarizations of the fundamental mode propagating at slightly different speeds. Because of the coating-induced stress-birefringence effects, the time-delay domain impulse response is expected to exhibit a dual lobe as a result of polarization mode dispersion (PMD). Measurements were taken to characterize the birefringence induced in this optical fiber.

After measuring the fiber using the OVA's transmission mode and optimizing the width of the time domain window, the time-delay domain impulse response of the DUT, plotted in the top graph of Figure 1, was examined. The pulse is recognized as broadened and its amplitude is modulated. While the modulation of the pulse creates a dual lobed structure near the peak, these sub-peaks did not result from the effects of PMD. This is confirmed by examining the PMD calculated for this DUT, which is plotted at the bottom of Figure 1; the PMD level is substantially less than the separation of the sub-peaks of the time-delay domain impulse response. The group delay, shown in

Figure 2, exhibits a well-defined linear slope. This indicates that pulse compression can be used as a tool to remove dispersion effects.



Type of Measurement: Transmission
Center Wavelength (nm): 1550.00
Wavelength Range (nm): 41.69
Scan Range (nm): 1529.32 - 1571.25
DUT Length Find Method: Broadband
Length of DUT (m): 60.431
☑ Continuous Mode
☐ Enable Averaging # 8
Filter Resolution BW (pm): 0.00
Matrix for Res BWs Below: A
TD Window Res BW (pm): 28.41
Convolved Res BW (pm): 28.41
Sync X-Axes To: Top
☑ Matrix A
☐ Matrix B
☐ Matrix C

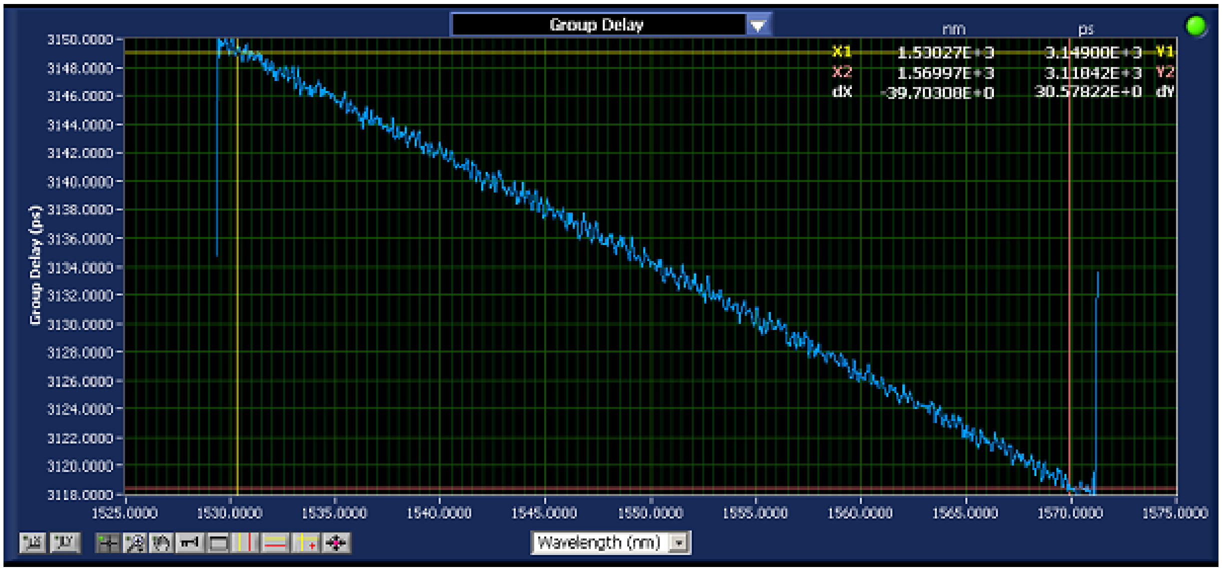
Figure 1. Insertion Loss and Time Domain Amplitude, Compression not Enabled

The pulse compression feature requires the user to input a reference wavelength, an average dispersion, and a dispersion slope. It is possible to find the average dispersion and dispersion slope parameters using the group delay, chromatic dispersion, and/or phase data. When working with the data, a number of different techniques may be used to find parameter values, including trial-and-error, estimation, and calculation. Estimation and trial-and-error techniques are performed using the OVA software. More exact calculations of the parameter values require saving OVA data to file and manipulating the data in a spreadsheet or in other curve analysis software. This section shows how the average dispersion may be estimated using the OVA's group delay data plot, and it demonstrates the calculation of both parameters from the group delay data.

The average dispersion parameter, d_a, is both the slope of the group delay and the mean value of the chromatic dispersion. The average dispersion parameter can be estimated using the OVA's group delay plot as shown in Figure 2. With the cursors positioned to select points near the beginning and end of the spectrum, the average group delay, $d_{a\,,}$ is estimated to be ~ -0.77 ps/nm by dividing the difference in group delay by the corresponding difference in wavelength. Note that as the group delay is measured over a specified length of fiber, the units of this parameter are [ps/nm] rather than [ps/nm · km].

The slope of the dispersion coefficient, d_s, is the slope of the chromatic dispersion data. This parameter can be estimated from the chromatic dispersion graph using a procedure similar to that used to estimate d_a from the group delay plot. For this device, there was no discernable slope on the chromatic dispersion data.

While the chromatic dispersion plot can be used to estimate both d_a and d_s, this may not be the preferred approach. The chromatic dispersion is calculated by taking the derivative of the group delay data, which results in the signal noise appearing more pronounced in the chromatic dispersion data. The value of d_a is frequently estimated more accurately and easily using the group delay graph.

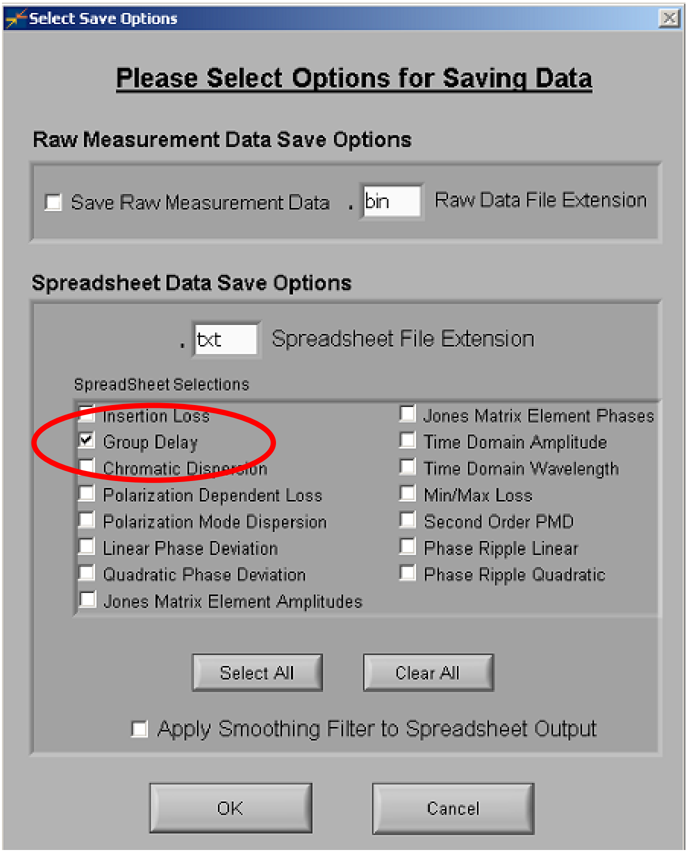


	nm	ps	
X1	1.53027E+3	3.14900E+3	Y1
X2	1.56997E+3	3.11042E+3	Y2
dX	-39.70300E+0	30.57822E+0	dY

Figure 2. Group Delay with Cursors Positioned to Estimate Slope

When it is necessary to determine the values of the pulse compression parameters more accurately than is possible using graphical estimation techniques, the parameters can be calculated from data saved to text file from the OVA. The calculations are performed in a spreadsheet or other program capable of curve analysis. As mentioned previously, the parameters may be calculated from phase, group delay, and chromatic dispersion data. The following procedure demonstrates a method that uses the group delay data.

The first step is to save the group delay data from the OVA to a text file. It is possible to specify which data files the OVA will save to file by accessing the ‘Select Data Save Options’ under the ‘File’ tab. When this window, shown in Figure 3, is open, ensure there is a check beside the *Group Delay* item.


Select Save Options

Please Select Options for Saving Data

Raw Measurement Data Save Options

☐ Save Raw Measurement Data . bin Raw Data File Extension

Spreadsheet Data Save Options

. txt Spreadsheet File Extension

SpreadSheet Selections

☐ Insertion Loss
☑ Group Delay
☐ Chromatic Dispersion
☐ Polarization Dependent Loss
☐ Polarization Mode Dispersion
☐ Linear Phase Deviation
☐ Quadratic Phase Deviation
☐ Jones Matrix Element Amplitudes
☐ Jones Matrix Element Phases
☐ Time Domain Amplitude
☐ Time Domain Wavelength
☐ Min/Max Loss
☐ Second Order PMD
☐ Phase Ripple Linear
☐ Phase Ripple Quadratic

☐ Apply Smoothing Filter to Spreadsheet Output

Figure 3. Configuring Data Options to Save Group Delay Data to a Text File

After the data file is opened in the curve analysis program, the average dispersion and the dispersion slope can be calculated. As was illustrated using the graphical method, the average dispersion, d_a [ps/nm], is calculated by determining the slope of a line fit to the group delay data.

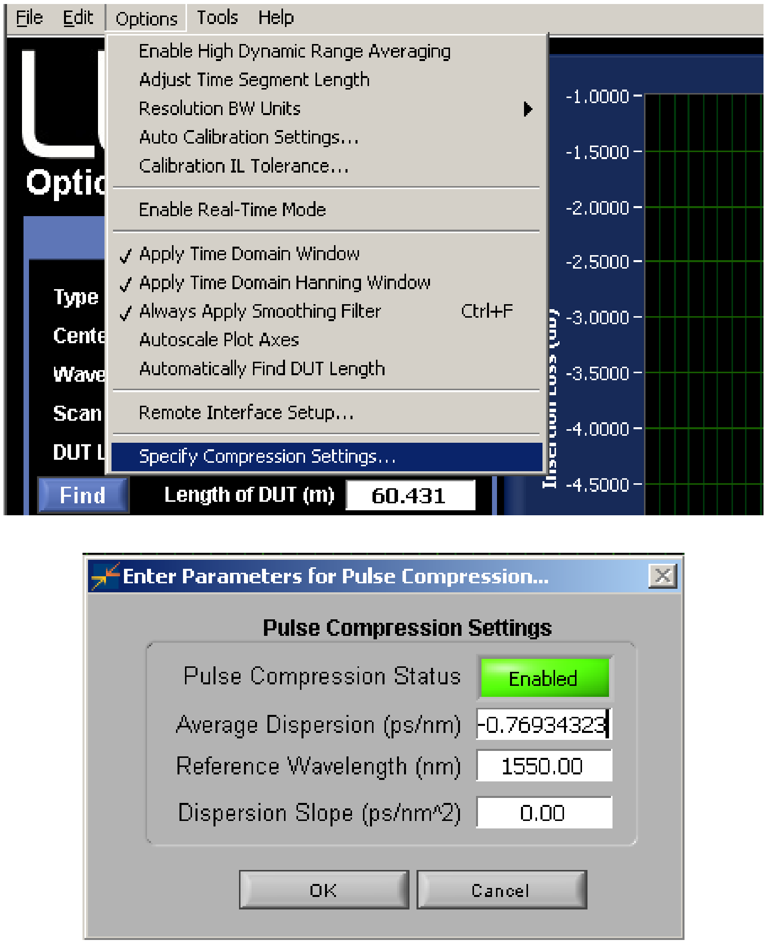
The first step in calculating the dispersion slope, d_s [ps/nm^2], from the group delay data is subtracting the linear term, $d_a \cdot \lambda$, from the group delay data:

$$GD_{Mod}(\lambda) = GD(\lambda) - d_a \cdot \lambda. \tag{8}$$

The next is to rescale the x-axis by subtracting λ_{ref} from λ, where λ_{ref} is defined as the center of the wavelength window. The second order coefficient is then found by performing a second order fit to GD_{Mod} as a function of $(\lambda - \lambda_{ref})$. Referencing Equation (4), the dispersion slope, d_s, is two (2) times the second order coefficient.

Following this procedure resulted in the calculation of d_a = -0.7693 [ps/nm], which agrees well with the value found using the graphical method, and a negligible value for d_s for the low bend-loss fiber. As the group delay affects the entire spectrum of this device, the reference wavelength was taken to be equal to the center wavelength of the measurement scan, 1550 nm.

With values of the average dispersion and the dispersion slope determined, the pulse compression feature can be enabled and customized for this DUT. This is done by first selecting the ‘Specify Compression Settings’ feature in the ‘Options’ tab, as shown at the top of Figure 4, and then entering the data corresponding to this DUT, as is shown in the image at the bottom of the figure. It is also necessary to toggle the *Pulse Compression Status* button to ‘Enabled’ for pulse compression to be applied to all subsequent measurements. Changes made to these settings will not affect previously acquired measurements.



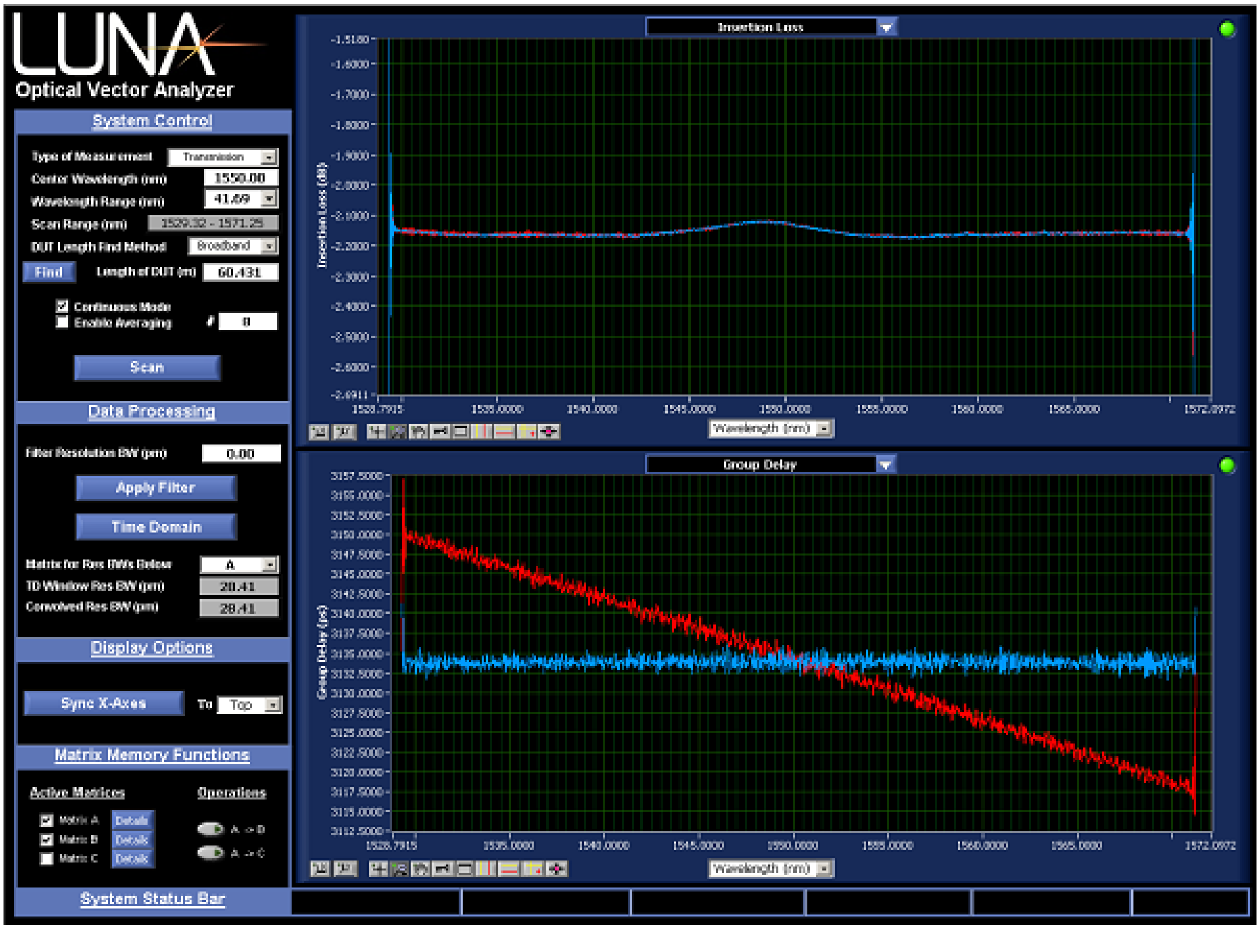
Length of DUT (m) 60.431

Pulse Compression Settings

Pulse Compression Status: Enabled
Average Dispersion (ps/nm): -0.76934323
Reference Wavelength (nm): 1550.00
Dispersion Slope (ps/nm^2): 0.00

Figure 4. Enabling and Specifying Values for the Compression Option

Prior to making a measurement of the device with the pulse compression feature enabled, the original uncompressed data were copied into Matrix B using the *Memory Matrix Functions* block on the front panel. The OVA writes new measurement data to Matrix A, which overwrites the previously-acquired measurement data residing in Matrix A. Moving the original measurement data to Matrix B allows this uncompressed device data to be retained and compared to the device data calculated with the pulse compression feature enabled. The insertion loss and group delay data calculated from the uncompressed and compressed impulse responses are plotted in Figure 5. The data calculated from the original uncompressed measurement are plotted in red and the data calculated from the subsequently-acquired compressed impulse response are plotted in blue. Both traces are plotted on the same graph by selecting Matrix A and Matrix B in the *Active Matrices* area of the *Matrix Memory Functions* block.



Type of Measurement: Transmission
Center Wavelength (nm): 1550.00
Wavelength Range (nm): 41.69
Scan Range (nm): 1529.32 - 1571.25
DUT Length Find Method: Broadband
Length of DUT (m): 60.431
☑ Continuous Mode
☐ Enable Averaging # 8
Filter Resolution BW (pm): 0.00
Matrix for Res BWs Below: A
TD Window Res BW (pm): 28.41
Convolved Res BW (pm): 28.41
To: Top
☑ Matrix A
☑ Matrix B
☐ Matrix C

Figure 5. Effects of Compression on Insertion Loss and Group Delay

The time-delay domain amplitudes of the two are shown in Figure 6. As in Figure 5, the curve corresponding to the uncompressed impulse response is plotted in red and that corresponding to the compressed impulse response is in blue. With pulse compression enabled, the calculated impulse response is narrower and possesses a greater maximum amplitude than that calculated without pulse compression. In addition, the compressed impulse response exhibits features obscured by the effects dispersion in the uncompressed data. The dual lobes of the compressed impulse response cannot be discerned in the uncompressed impulse response. The separation of the sub-peaks of the compressed impulse response is consistent with the average PMD measured for the device and are indicative of the birefringence present in the DUT.

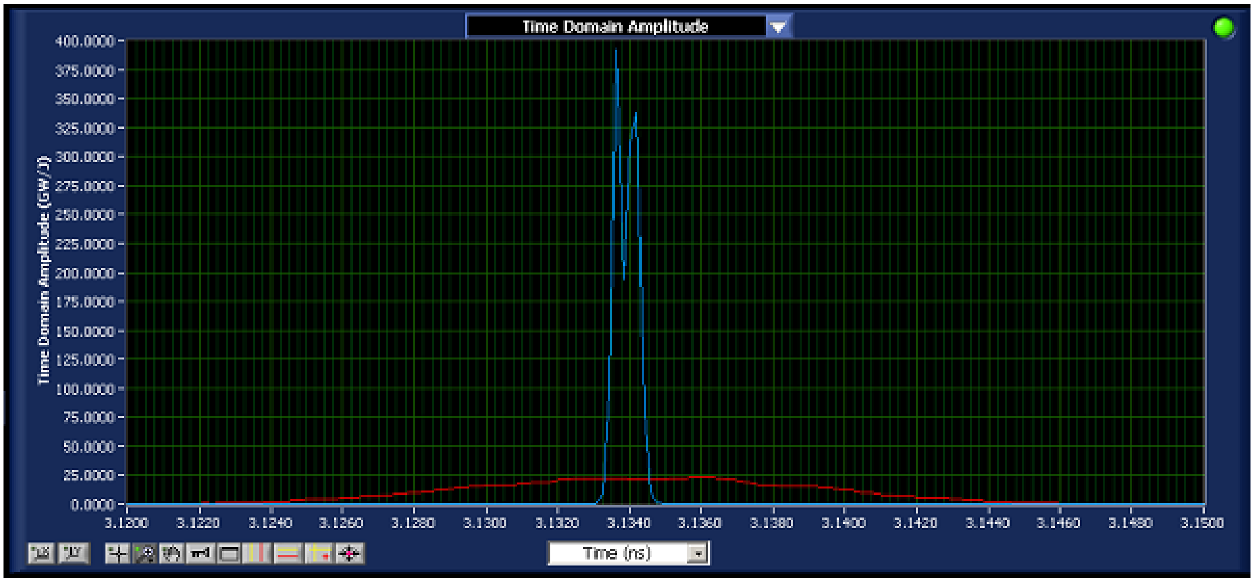
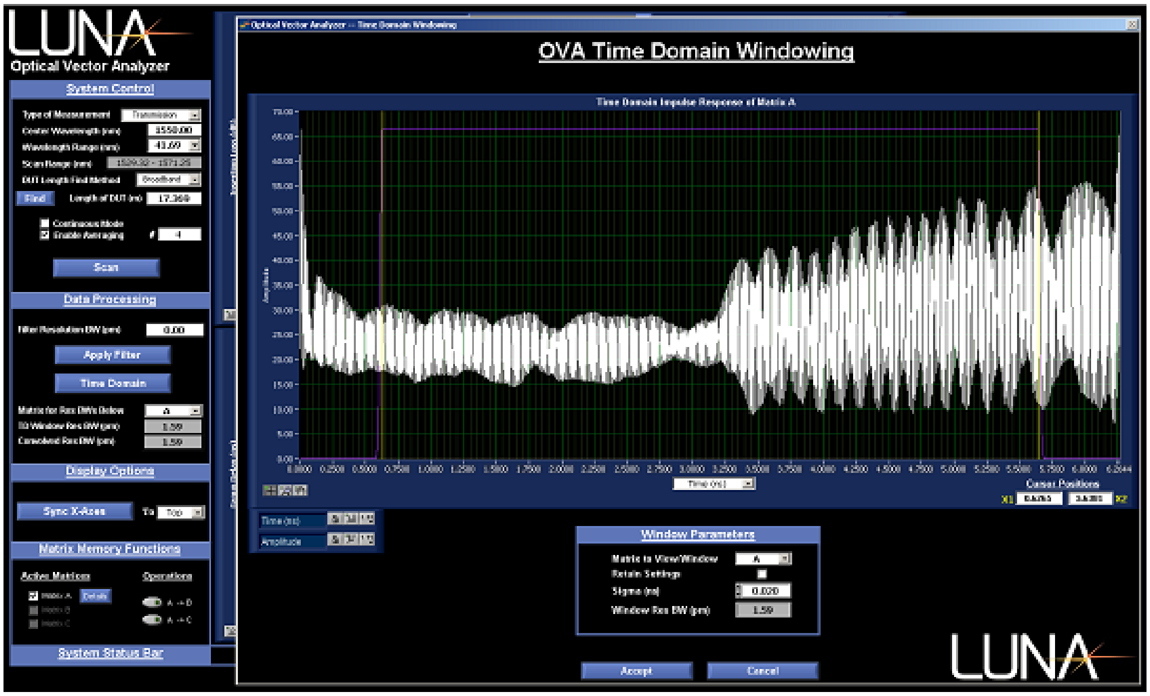


Figure 6. Effects of Compression on the Time Domain Amplitude

5 Using Impulse Response Compression to Characterize Highly Dispersive Devices

Compression can allow highly dispersive devices to be characterized by the OVA. When the impulse response duration of the DUT is wider than the extent accommodated by the OVA, the impulse response calculated by the OVA is corrupted and typically has an unusual appearance when plotted. The impulse response calculated for a dispersion compensation module (DCM), which has a manufacturer-specified 10 ns/nm dispersion over the 1549 nm to 1551 nm spectral range, is shown in Figure 7. This measurement was acquired, with the compression feature disabled, while the OVA was operating in transmission mode. Because the impulse response is corrupted, the phase, group delay, and chromatic dispersion data calculated from the corrupted impulse response are also corrupted. It is therefore not possible to directly use these OVA data to calculate the average dispersion, d_a, and the dispersion slope, d_s. of the device. Graphs of the corrupted insertion loss and group delay data are shown in Figure 8.

One method of implementing pulse compression under these circumstances is to use a combination of trial-and-error and estimation to identify serviceable values for the average dispersion and dispersion slope parameters. If the approximate dispersion of the device is known, its value can be used to enable the compression option as shown in Figure 4. Then a second measurement scan can be acquired. If the compressed impulse response duration computed from the second measurement is less than the upper limit set by the OVA, the operator can then choose to further refine the compression parameters, using the techniques described in the previous section, or to characterize the device without making further modifications to the compression parameters.



System Control

Type of Measurement: Transmission
Center Wavelength (nm): 1550.00
Wavelength Range (nm): 41.69
Scan Range (nm): 1529.32 - 1571.25
DUT Length Find Method: Broadband
Find — Length of DUT (m): 17.369
☐ Continuous Mode
☑ Enable Averaging # 4

Data Processing

Filter Resolution BW (pm): 0.00
Matrix for Res BWs Below: A
TD Window Res BW (pm): 1.59
Convolved Res BW (pm): 1.59

Display Options

Sync X-Axes To: Top

Matrix Memory Functions

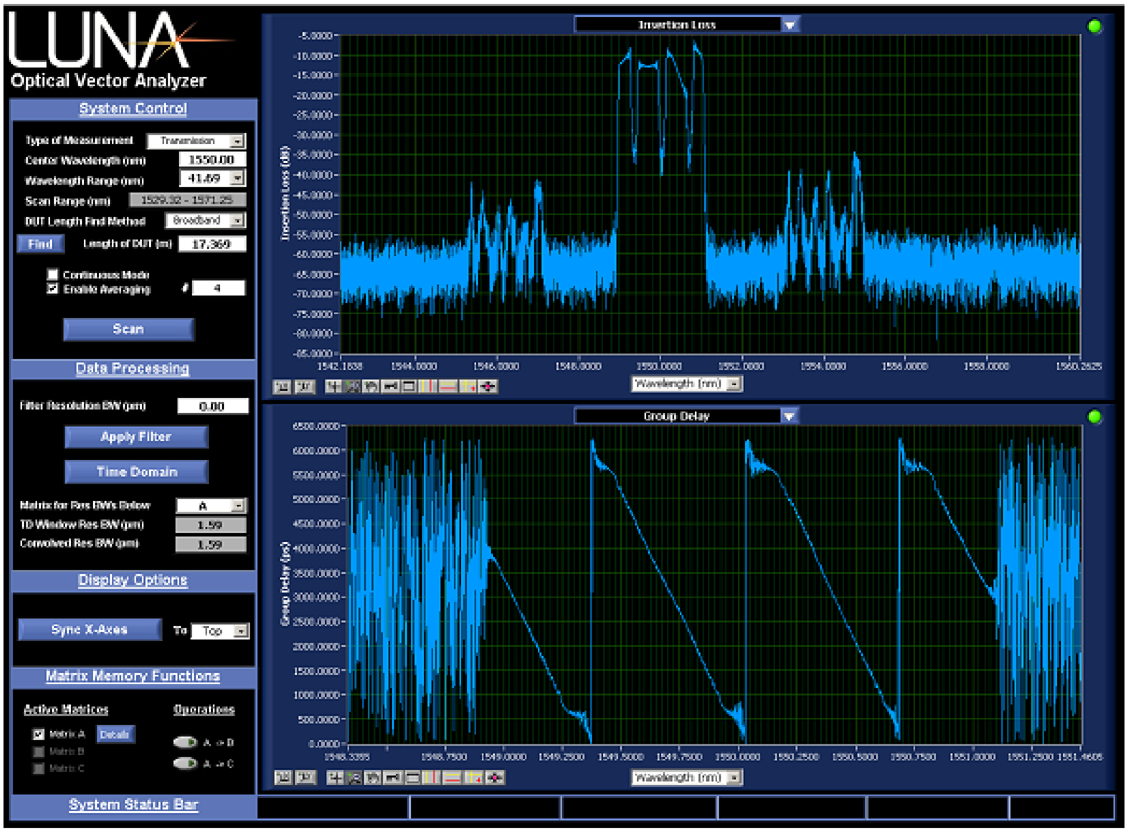
Active Matrices
☑ Matrix A
☐ Matrix B
☐ Matrix C

System Status Bar

Window Parameters

Matrix to View/Window: A
Retain Settings: ☐
Sigma (ns): 0.020
Window Res BW (pm): 1.59

Figure 7. Corrupted Uncompressed Impulse Response of a Highly Dispersive DUT



System Control

Type of Measurement: Transmission
Center Wavelength (nm): 1550.00
Wavelength Range (nm): 41.69
Scan Range (nm): 1529.32 - 1571.25
DUT Length Find Method: Broadband
Find — Length of DUT (m): 17.369
☐ Continuous Mode
☑ Enable Averaging # 4

Data Processing

Filter Resolution BW (pm): 0.00
Matrix for Res BWs Below: A
TD Window Res BW (pm): 1.59
Convolved Res BW (pm): 1.59

Display Options

Sync X-Axes To: Top

Matrix Memory Functions

Active Matrices
☑ Matrix A
☐ Matrix B
☐ Matrix C

System Status Bar

Figure 8. Corrupted Insertion Loss and Group Delay of a Highly Dispersive DUT

The pulse compression parameters may also be calculated from device measurement data. If this option is preferred, it is recommended that the device be interrogated using the optical frequency domain reflectometry (OFDR) software. The OVA software should be exited before opening the OFDR software. The calculation approach may be preferred if little is known about the device dispersion, or if it is important to more accurately determine the values of the average dispersion and dispersion slope.

The OFDR measurement technique is compatible with devices that possess wider impulse responses than are accommodated by the OVA. The OFDR software allows the group delay and other parameters of highly dispersive devices to be measured and saved to text file. Figure 9 shows the time-delay domain amplitude of the DCM over the full measurement range. The narrow peak at approximately 29 ns is the reflection from the optical connector at the input of the DCM, the wide feature centered at approximately 83 ns is the DCM, and the narrow peak at approximately 98 ns is the optical connector at the output of the DCM.

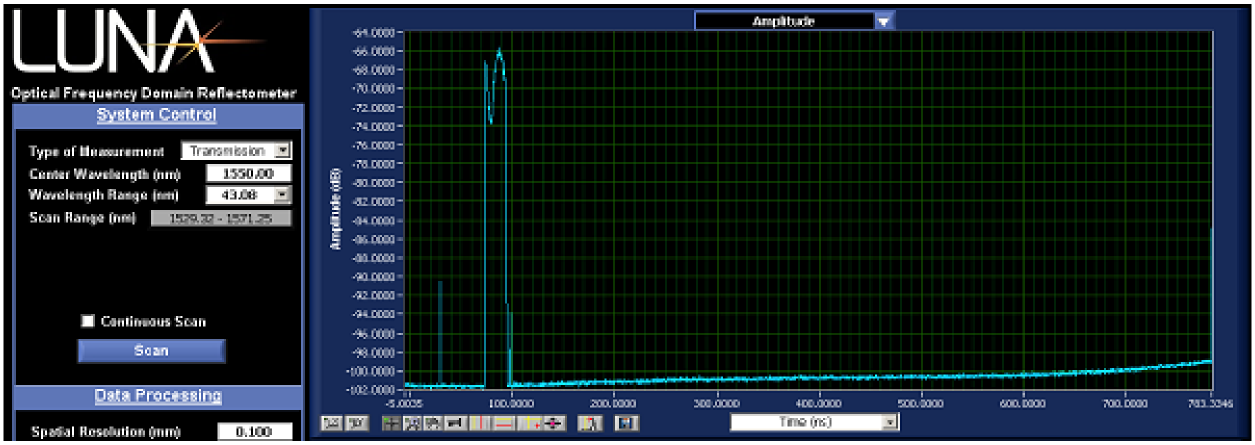
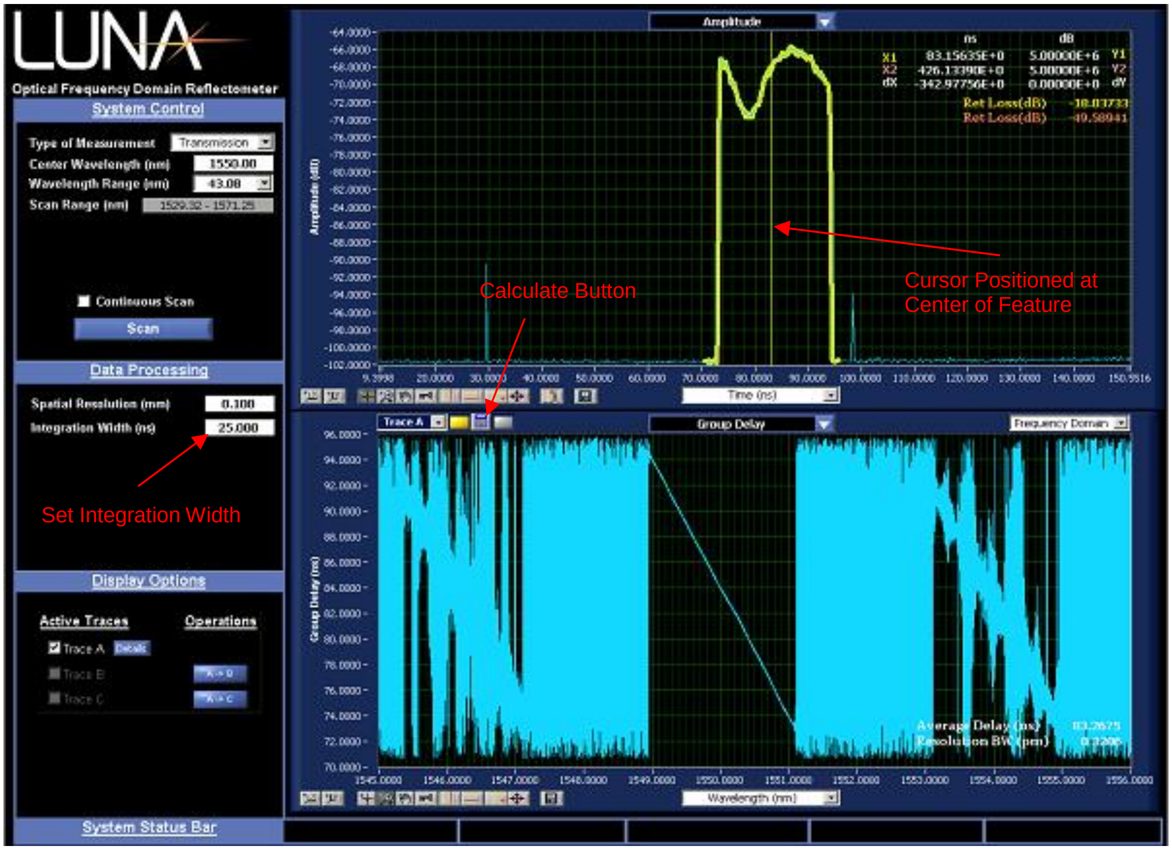

Type of Measurement: Transmission
Center Wavelength (nm): 1550.00
Wavelength Range (nm): 43.08
Scan Range (nm): 1529.32 - 1571.25
☐ Continuous Scan
Spatial Resolution (nm): 0.100

Figure 9. OFDR Measurement of the DCM

As is shown in Figure 10, the group delay is calculated by adjusting the x-axis span to better view the DCM feature, enabling the cursors, positioning one cursor at the center of the feature, setting the integration width to encompass the entire feature, and calculating the group delay. The calculated group delay appears in the lower graph. Unlike the low bend-loss fiber examined in the previous section, whose passband extended over the entire examined spectral range, the passband of the DCM is restricted to approximately the region between 1549 nm and 1551 nm.

Cursors in the OFDR software can be used to estimate the average dispersion (group delay slope, d_a) from the group delay data in the manner illustrated in Figure 2 of the previous section. When this is done, group delay data points at either end of the passband, rather than at either end of the wavelength range, should be selected. It is also possible to save the computed group delay data from the OFDR software to file so that it can be manipulated in a spreadsheet or other data analysis software. Before saving the data file, ensure the group delay data will be included by opening the ‘Select Data File Options’ under the ‘File’ tab. Checks should appear next to *Save File for Lower Graph* and *Group Delay*, as indicated in Figure 11.



Type of Measurement: Transmission

Center Wavelength (nm): 1550.00

Wavelength Range (nm): 43.08

Scan Range (nm): 1529.32 - 1571.25

Spatial Resolution (mm): 0.100

Integration Width (ns): 25.000

	ns	dB	
X1	83.15635E+0	5.00000E+6	Y1
X2	426.13390E+0	5.00000E+6	Y2
dX	-342.97756E+0	0.00000E+0	dY

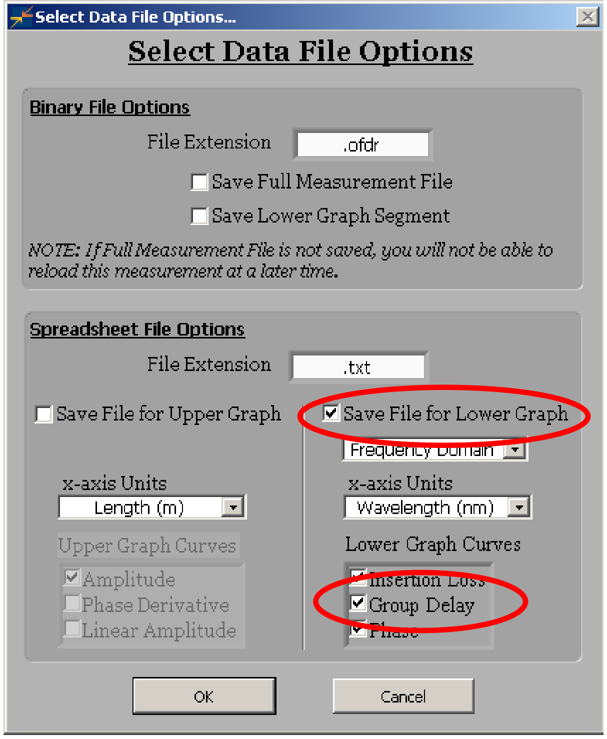
Ret Loss(dB) -18.03733

Ret Loss(dB) -49.58941

Average Delay (ns) 83.2675

Resolution BW (pm) 0.3206

Figure 10. Calculating Group Delay Using the OFDR Software



Select Data File Options...

Select Data File Options

Binary File Options

File Extension: .ofdr

☐ Save Full Measurement File

☐ Save Lower Graph Segment

NOTE: If Full Measurement File is not saved, you will not be able to reload this measurement at a later time.

Spreadsheet File Options

File Extension: .txt

☐ Save File for Upper Graph

☑ Save File for Lower Graph

Frequency Domain

x-axis Units: Length (m)

x-axis Units: Wavelength (nm)

Upper Graph Curves

☑ Amplitude

☐ Phase Derivative

☐ Linear Amplitude

Lower Graph Curves

☑ Insertion Loss

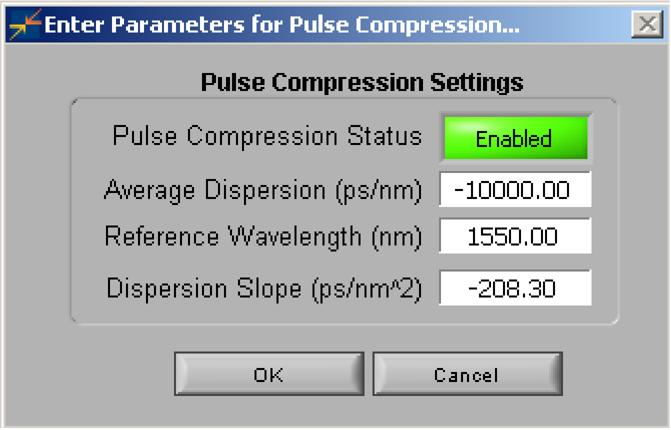
☑ Group Delay

☑ Phase

Figure 11. Configuring Data File Saving Options in the OFDR Software

The average dispersion and the dispersion slope, d_s, can be calculated from the saved group delay data using the procedure outlined in the previous section, which follows Figure 3. These calculations were performed using only the group delay data falling between the edges of the DCM passband, 1549 nm to 1551 nm. The reference wavelength, λ_{ref}, coincides with the center of the passband and is 1550 nm. The average dispersion, d_a, is found to be equal to the quoted value, -10,000 ps/nm, and the slope of the dispersion, d_s, has a calculated value of -208.30 ps/nm^2.

After closing the OFDR software, the OVA software can be opened and the pulse compression option configured. The average dispersion, dispersion slope, and reference wavelength parameters are entered and pulse compression is enabled, as shown in Figure 12.



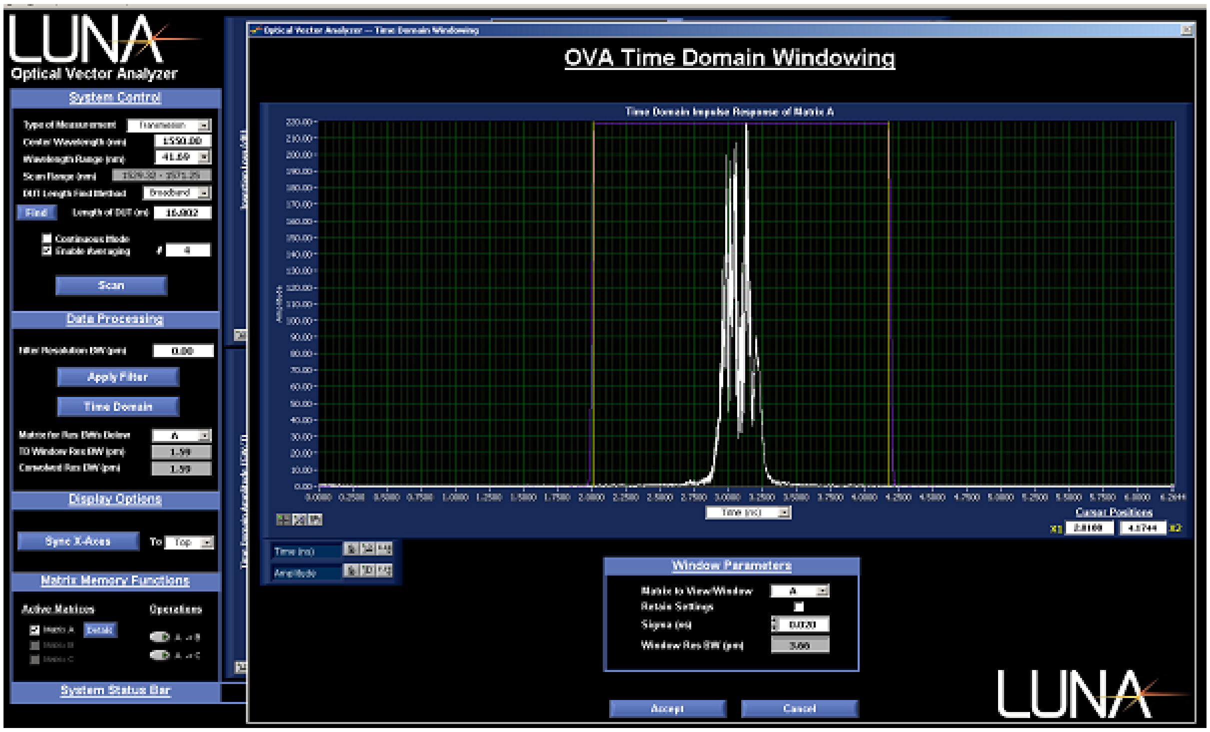
Enter Parameters for Pulse Compression...

Pulse Compression Settings

Pulse Compression Status: Enabled
Average Dispersion (ps/nm): -10000.00
Reference Wavelength (nm): 1550.00
Dispersion Slope (ps/nm^2): -208.30

Figure 12. Customizing the Pulse Compression Parameters for the DCM

With the pulse compression feature enabled, a measurement of the DCM was acquired. The compressed impulse response of the device is shown in Figure 13. Unlike the uncompressed and corrupted impulse response shown in Figure 7, the compressed impulse response has a well-defined extent and its duration is comfortably accommodated by the OVA. The insertion loss and group delay calculated using the compressed impulse response are shown in Figure 14. With the removal of the average dispersion and slope of the dispersion from the phase of the device response, the effects of the higher order dispersion terms on the group delay are better revealed. Pulse compression also has the effect of flattening the insertion loss.



Type of Measurement: Transmission
Center Wavelength (nm): 1550.00
Wavelength Range (nm): 41.69
Scan Range (nm): 1529.32 - 1571.25
DUT Length Find Method: Broadband
Length of DUT (m): 16.802
☐ Continuous Mode
☑ Enable Averaging # 4
Filter Resolution BW (pm): 0.00
Matrix for Res BWs Below: A
1D Window Res BW (pm): 1.59
Convolved Res BW (pm): 1.59
To: Top
Cursor Positions: X1 2.0100, 4.1744 X2

Window Parameters
Matrix to View/Window: A
Retain Settings ☐
Sigma (ns): 0.020
Window Res BW (pm): 3.66

Figure 13. Impulse Response of the DCM Obtained Using Compression

Type of Measurement: Transmission
Center Wavelength (nm): 1550.00
Wavelength Range (nm): 41.69
Scan Range (nm): 1529.32 - 1571.25
DUT Length Find Method: Broadband
Length of DUT (m): 16.802
☐ Continuous Mode
☑ Enable Averaging # 4
Filter Resolution BW (pm): 0.00
Matrix for Res BWs Below: A
1D Window Res BW (pm): 3.66
Convolved Res BW (pm): 3.66
To: Top
☑ Matrix A
☐ Matrix B
☐ Matrix C

Figure 14. Insertion Loss and Group Delay of DCM with Compression Enabled

6 Summary of the OVA Compression Option

The pulse compression feature subtracts user-specified constant values from the second and third order dispersion terms of the device response, which results in the calculation of a compressed time-domain impulse response. Enabling the compression feature is mandatory for obtaining uncorrupted measurements for highly dispersive devices: the OVA optical network accommodates impulse response durations of 6 ns or less if the DUT is measured in transmission and half or less of that value if it is measured in reflection. In addition, pulse compression can be used as a tool to sharpen features broadened by devices with lesser levels of dispersion.

The two parameters the OVA uses to mathematically compress the impulse response are the slope of the group delay (average dispersion) and the dispersion slope. These can be found from the device’s phase, group delay, or chromatic dispersion data. This document demonstrates how they may be obtained from the group delay of the DUT. If the device is highly dispersive and an uncorrupted calculation of the impulse response cannot be obtained with the OVA software, the data necessary to compute the pulse compression parameters can be obtained using the OFDR software.

The pulse compression feature was shown to sharpen the impulse response of a length of dispersive and slightly birefringent fiber. Compression was not necessary to allow the OVA to calculate an uncorrupted impulse response, but compression was necessary to sharpen and reveal the dual-peaked structure of the impulse response. Pulse compression was also demonstrated to allow a highly dispersive DCM to be characterized by the OVA. As the total delay, ~ 20 ns, of the DCM could not be accommodated by the OVA, the pulse compression parameters were calculated from the group delay data obtained from the OFDR software. These parameters were used to configure the OVA’s pulse compression feature, which enabled the DCM to be characterized by the OVA.

7 References

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