
LUNA
DEFYING IMPOSSIBLE.

Luna Innovations Business Segments

- **Instrumentation, Test and Measurement Products**
  - Sensing Systems
  - Telecommunications
- **Healthcare Products**
  - Medical Devices
  - Nanomedicines
- **Technology Development "Engine of Innovation"**
  - Long-term Contracts
  - Intellectual Property
  - Core areas:
    Sensing & Instrumentation; Materials, Health Sciences

Luna Technologies Division

- **Proven advanced fiber optic test solutions for**
  - Telecommunications
  - Military and Aerospace
  - Government and Institutional Research
  - Industrial Process Monitoring and Sensing
- **Award-winning leader in fiber optic test**
  - Polarization and dispersion measurement and analysis
  - High resolution optical time domain reflectometry (OBR)
  - Distributed fiber optic sensing
- **Incorporated in 2000 with Products Division in Blacksburg, VA**
- **Global sales in 20 countries**

LUNA | Industry Leading Customers

Products Overview

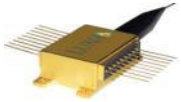
Optical Network Analyzers

Optical Vector Analyzer™ (OVA)

Reflectometers

Optical Backscatter Reflectometer™ (OBR)

Switches and Laser Sources



PHOENIX 1400

Sensing

Optical Distributed Sensor Interrogator (ODiSI)

Reflectometers – OBR Overview

Optical Backscatter Reflectometer™ (OBR)

OBR 4600
Benchtop Model

- High resolution fiber-optic component manufacturing, installation and maintenance testing
  - Avionics
  - Ship-board
  - Mobile Platforms
  - Secure Networks

OBR 4200

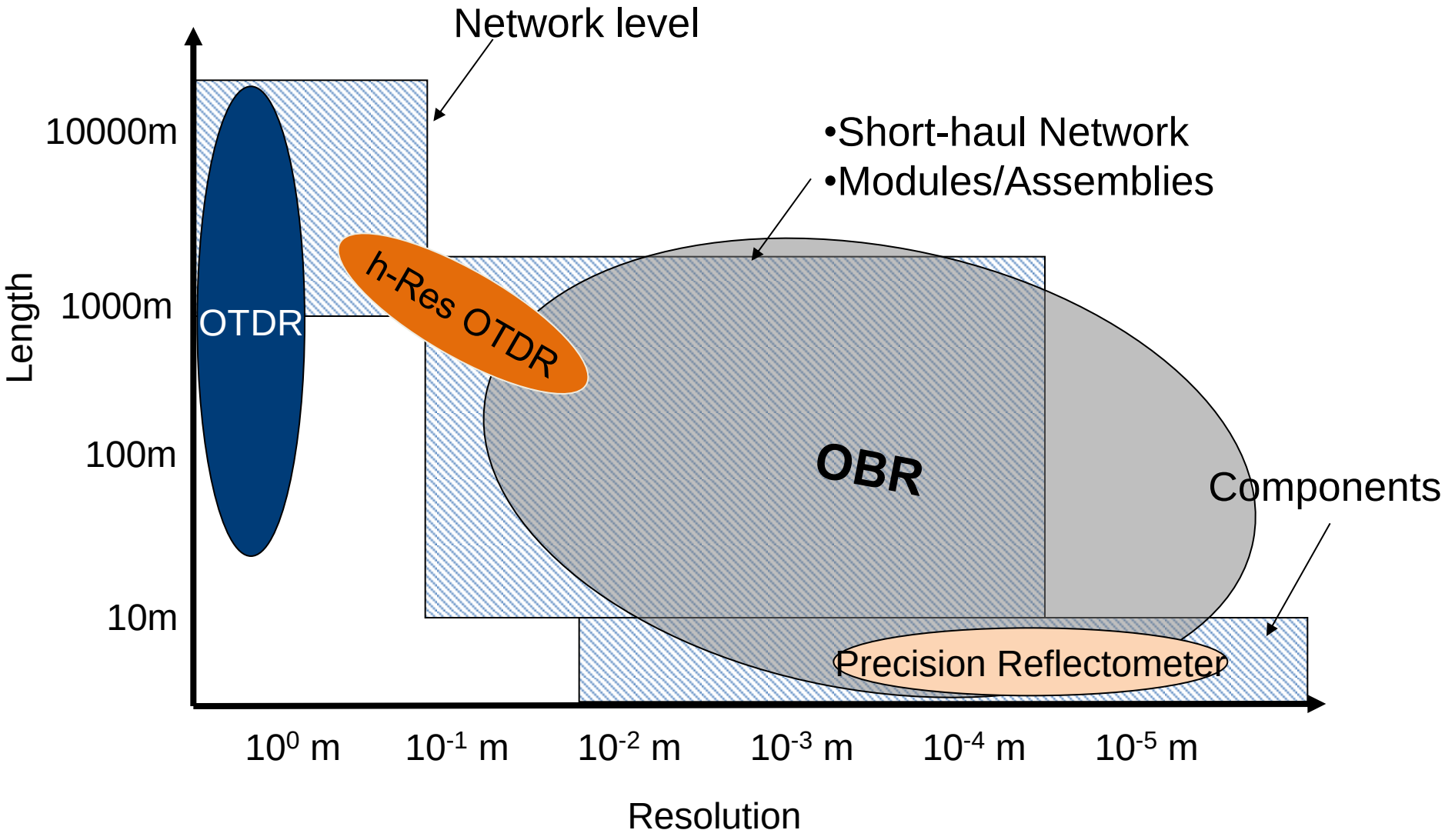
- Testing, installation, maintenance and monitoring for short run networks
- Avionics and shipboard network installation and maintenance
- Troubleshooting for single and multimode networks
- Simultaneous, single ended IL and RL measurements

Optical Backscatter Reflectometer™ (OBR)

High Resolution "OTDR"

- High resolution fiber optic component manufacturing, installation and maintenance testing
  - Component manufacturing
  - Avionics
  - Ship-board
  - Mobile Platforms
  - Secure Networks
- Unprecedented inspection and diagnostic capabilities for fiber optic industry
- Industries' *only* micrometer resolution OTDR designed for testing components, modules and assemblies
- More comprehensive testing and inspection in less time

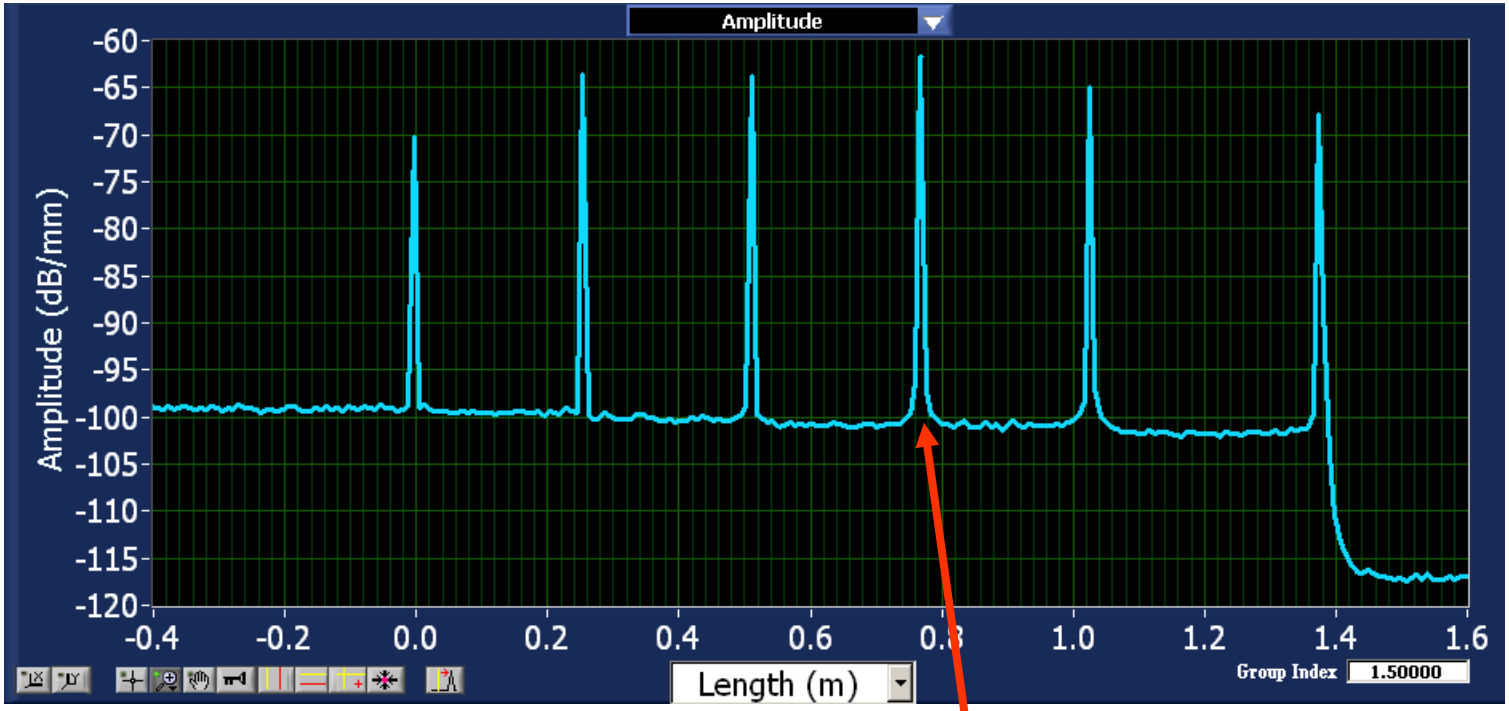
Reflectometry Techniques



OBR Applications

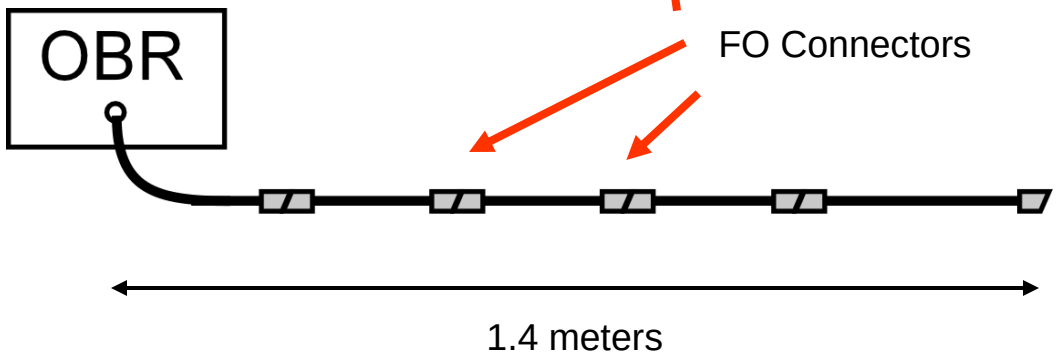
- IL/RL verification – ensure network uptime
- High-resolution fault location
  - Bend, break, bad splice, bad connector
- Failure mode analysis
  - Fiber, connector, splice, Tx/Rx
- Precise fiber length/skew measurement
- Fiber and component management
  - Incoming inspection, manufacturing verification, physical layer aging
- Distributed strain and load sensing
  - Network integrity inspection, critical system health monitoring, airframe health monitoring, 3-D wire system positioning

Example - Fiber and Connectors

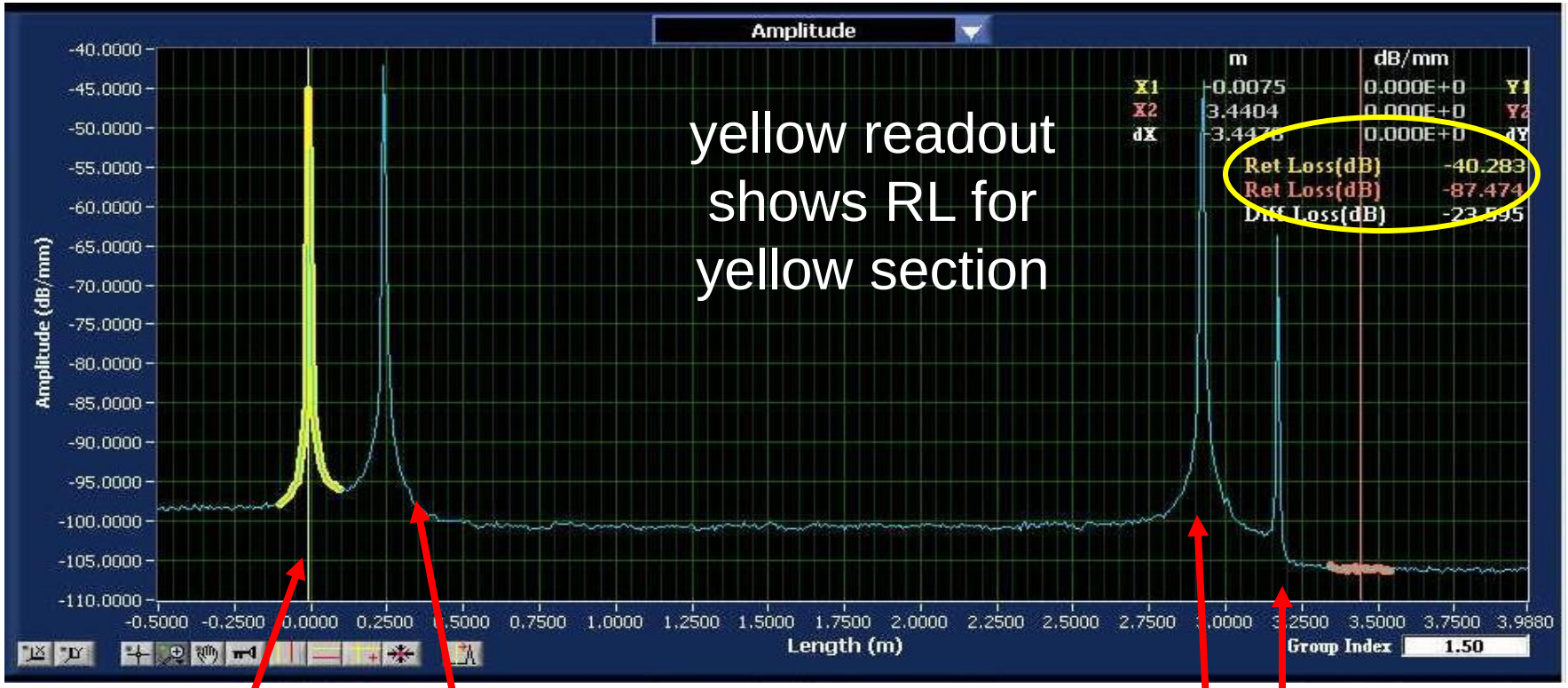


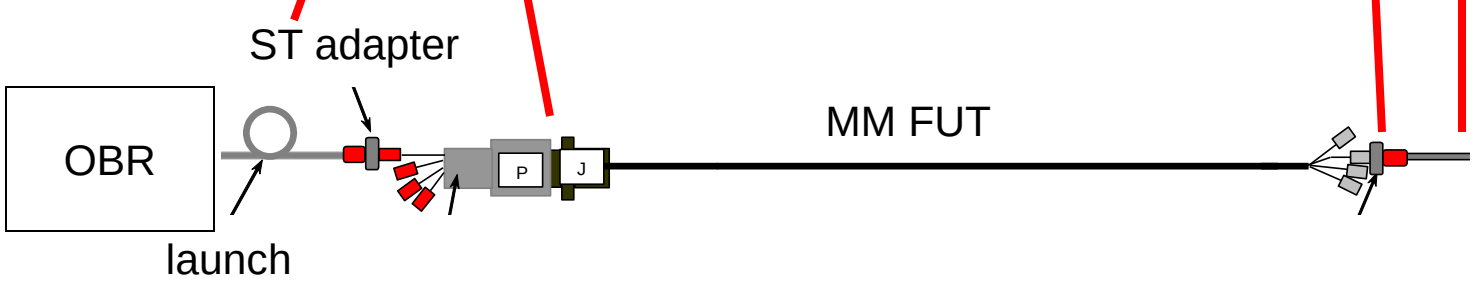
125 dB

20 dB

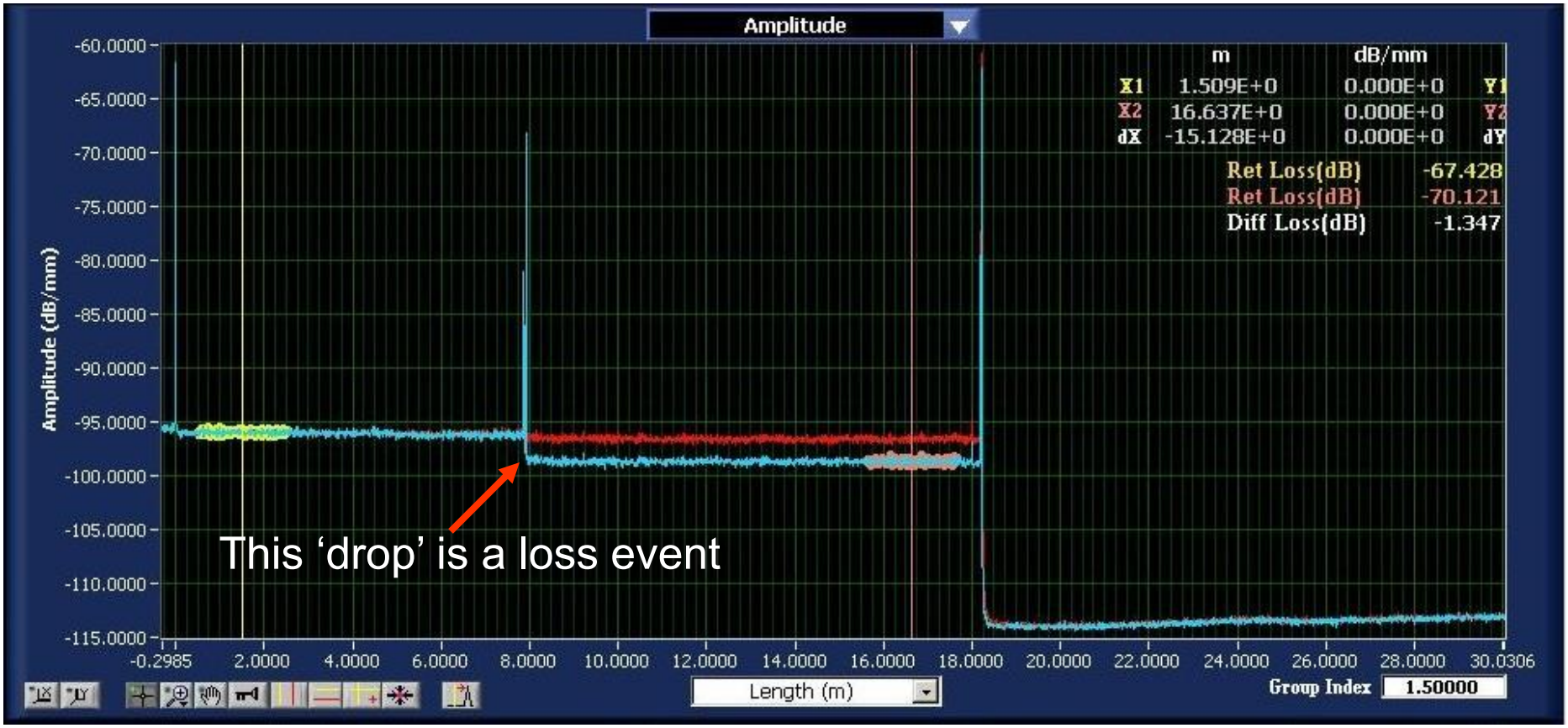


Measure Return Loss



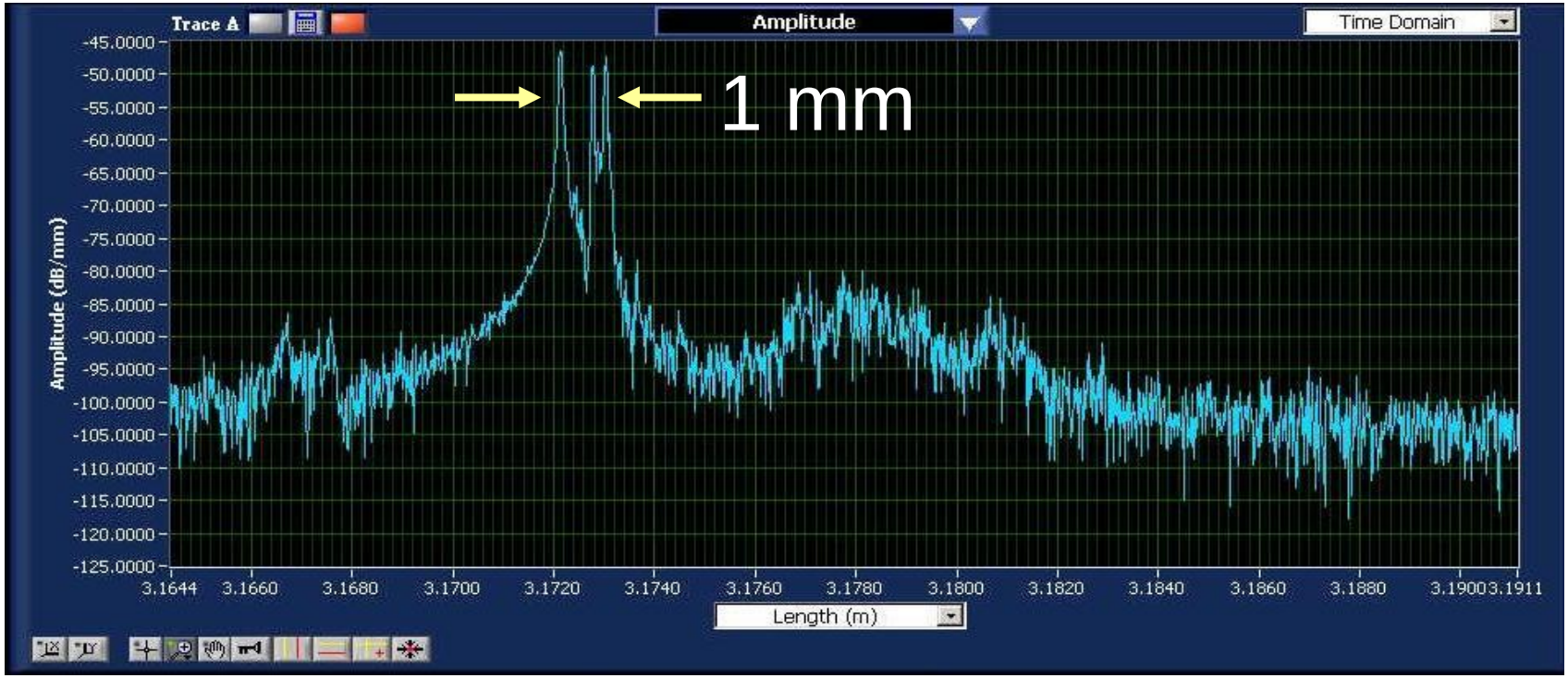


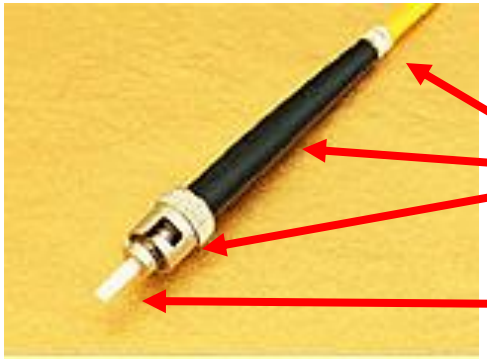
Measure Insertion Loss



Red = initial measurement
Blue = measurement at later time showing loss

OBR – High Resolution



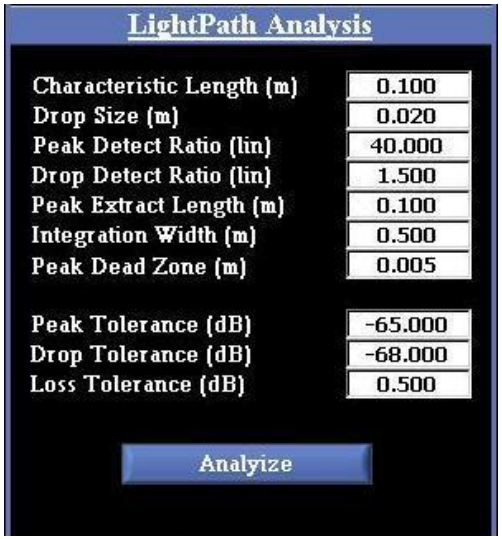


Discriminate between faults here…

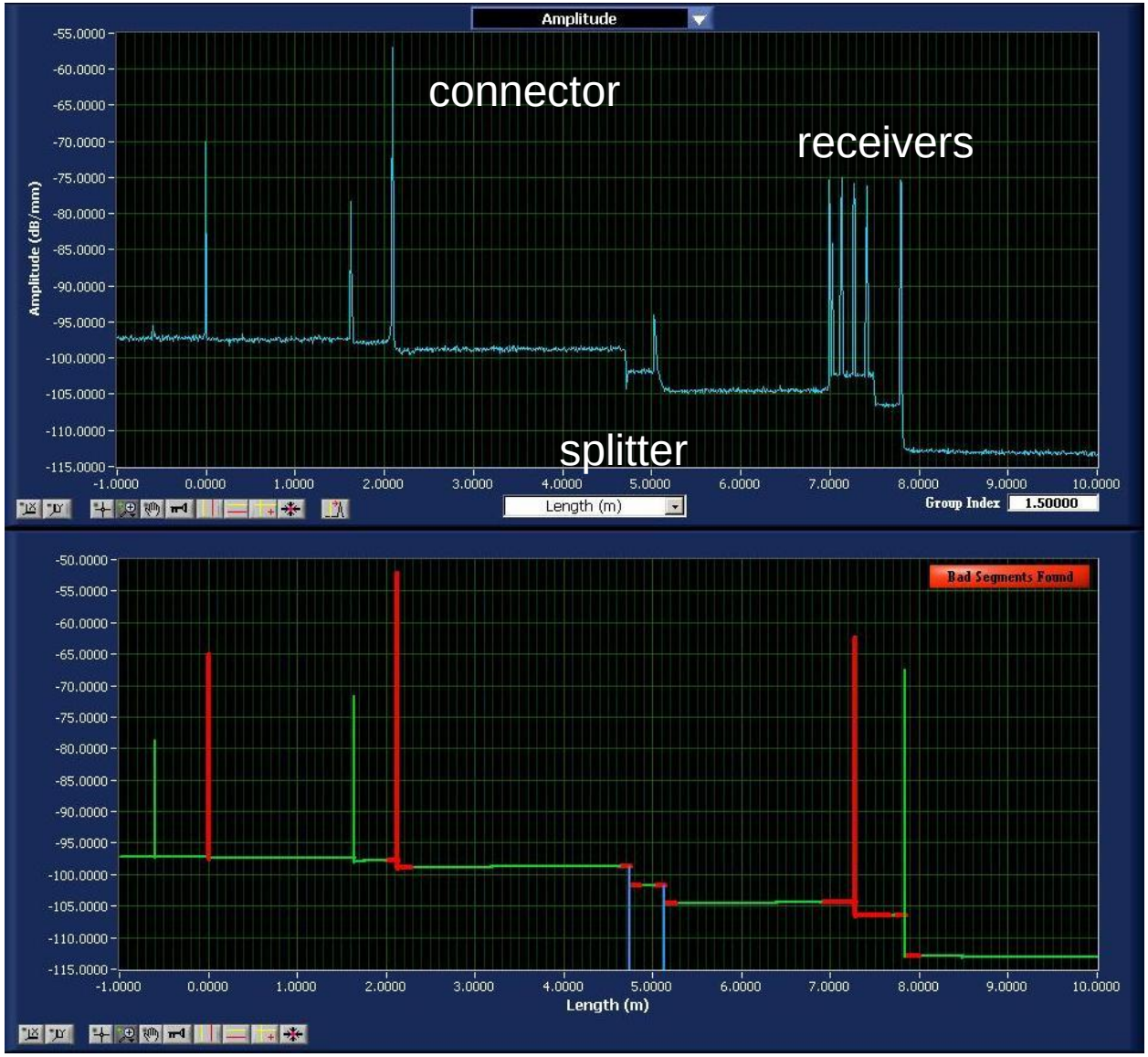
…and here

Automated Analysis

Define a mask

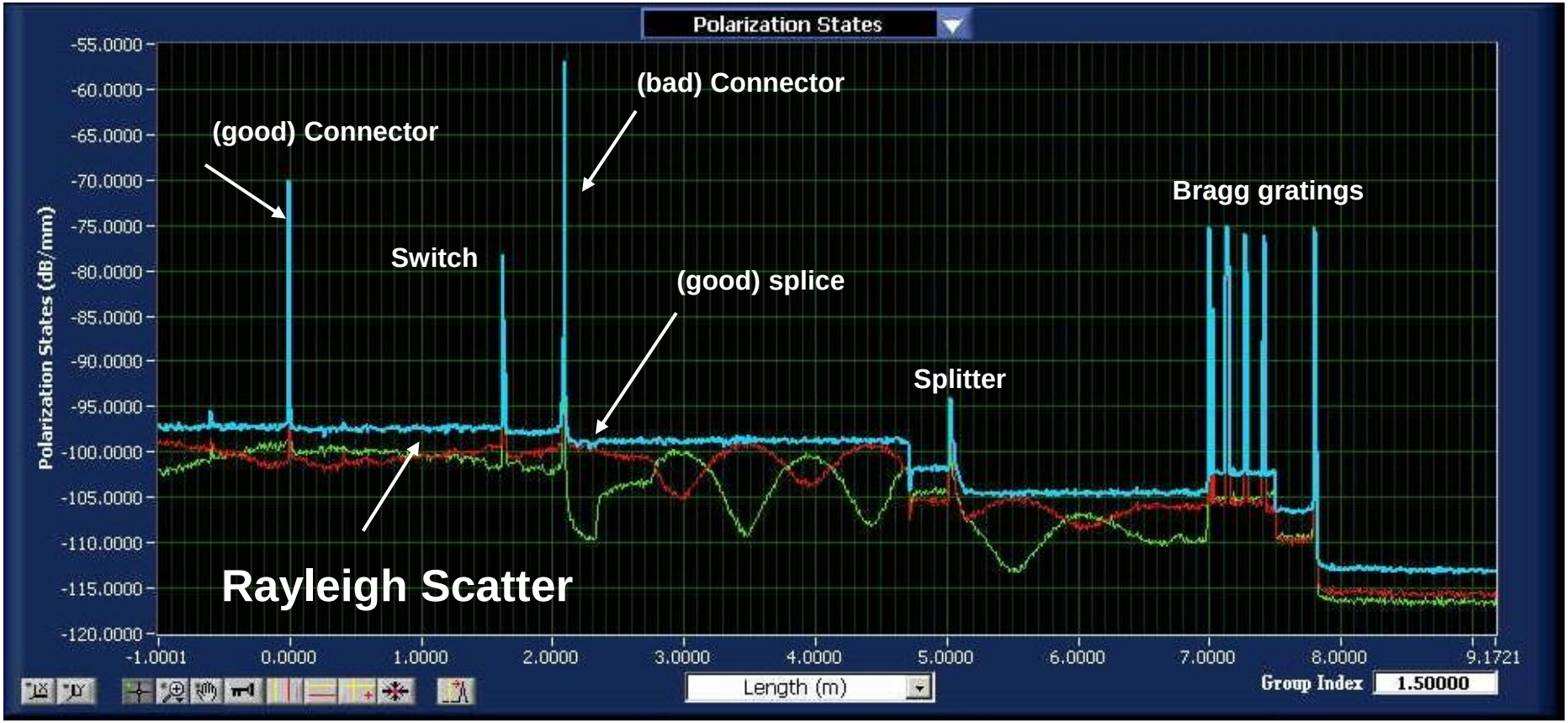


Automatic Pass/Fail



Rayleigh Scatter Measurement

- OFDR offers unprecedented sensitivity

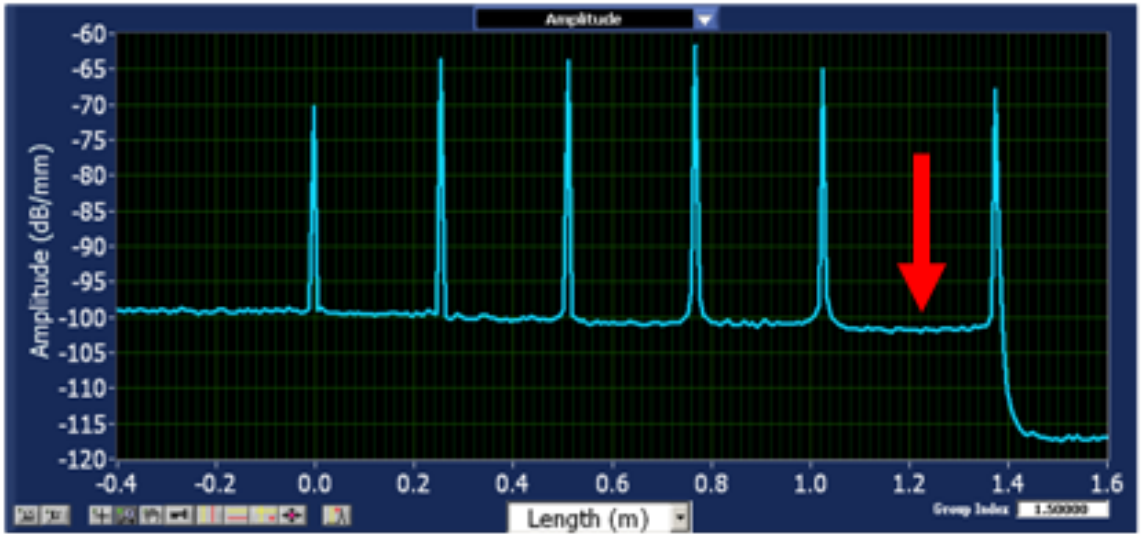


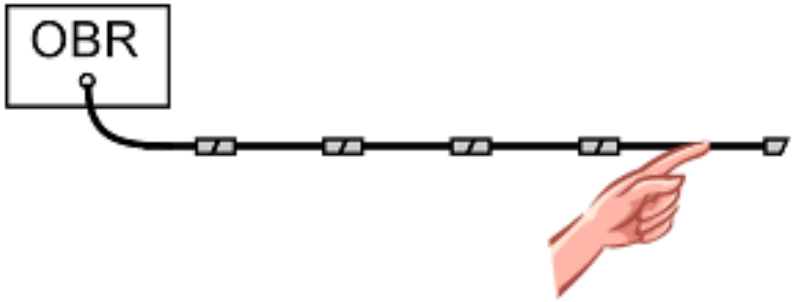
The fiber itself can be used as the sensor

- Rayleigh Sensing
- Standard telecom grade SMF becomes the sensor

Locate by Temperature

Distributed temperature can be used as a position locator in most standard fiber types





New - OBR 4600 Overview

- Improved data transfer and processing
- Full range scan with highest resolution in less than 7 s with fast scanning option, more than 4 x faster than OBR 4400
- Over 3 Hz scan rate for 5 nm scan with spot scanning option, over 10 x faster than OBR 4400
- Perform 2 km scan with 1 mm resolution in 20 s, over 2 x faster than with OBR 4400
- New amplitude comparison feature
- Improved Sensing Algorithms for more robust performance with higher strains and temperatures

OPTICAL BACKSCATTER REFLECTOMETER™
(Model OBR 4600)

OBR 4600 Sensing Improvements

Faster:

- Faster scanning results in low sensitivity to vibration
- With spot scan option, perform 5 nm scans at > 2 Hz

Better:

- Improved algorithms process sensing data faster
- Algorithms provide more robust sensing, able to accommodate higher strains over longer distances by accounting for accumulated shifts. Also better able to accommodate rapid changes in strain or temperature.

Optical Backscatter Reflectometer™ (OBR) 4200

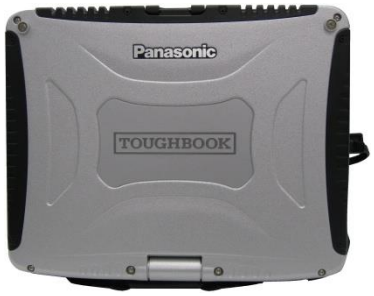
KEY FEATURES AND HIGHLIGHTS

- Fully portable, battery operated
- Rugged design for harsh environments
- Toughbook® compatible
- Millimeter resolution over 500 meters
- Industry's only portable ultra-high resolution OTDR

APPLICATIONS

- Testing, installation, maintenance and monitoring for short run networks
- Avionics and shipboard network installation and maintenance
- Troubleshooting for single and multimode networks
- Simultaneous, single ended IL and RL measurements

Optical Backscatter Reflectometer™ (OBR 4200)



OBR 4200 vs. 4600

Preliminary Specifications

Spec	OBR 4200	OBR 4600
λ range	1540 +/- 1nm	O, C, L
Sensitivity	-125 dB	-130 dB
Event Resolution	3 mm	0.01 mm
IL Dynamic Range	16 dB	18 dB
RL Dynamic Range	50 dB	60 dB
Length range	500 m	70m or 2km

OBR Summary

- Luna still offers the industry's only zero-dead-zone "OTDR" functionality
- Luna OBR's not only precisely identify fault locations, including bends, they measure loss at each event
- Luna's high resolution reflectometers:
  - Provide unprecedented visibility into components and short-run fiber networks
  - Allow users to attain higher quality optical systems in less time and at lower cost
- Luna continues to lead the market and answer customer needs, with the *New OBR 4200*

Reflectometer Summary

- Luna offers the industry's only zero dead-zone OTDR functionality

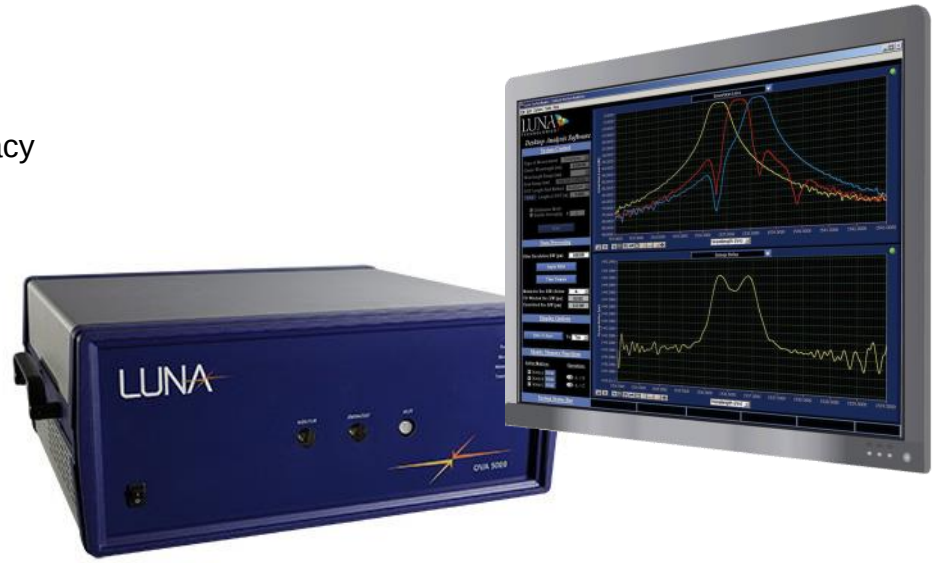
- Luna's high resolution reflectometers:
  - Provide unprecedented visibility into components and short-run fiber networks
  - Allow users to attain higher quality optical systems in less time and at lower cost

Optical Network Analyzers – OVA Overview

Optical Vector Analyzer™ (OVA)

Telecommunications Test

- Fiber optic component manufacturing test
- Industry-leading combination of speed and accuracy
- Key enabler in manufacturing of “next generation” optical network elements
- Integrated reflectometer (OFDR) capability



- Insertion Loss (IL)
- Polarization Dependent Loss (PDL)
- Group Delay (GD)
- Chromatic Dispersion (CD)
- Polarization Mode Dispersion (PMD)
- Optical Time Domain Windowing
- Jones Matrix elements
- Optical Phase Response

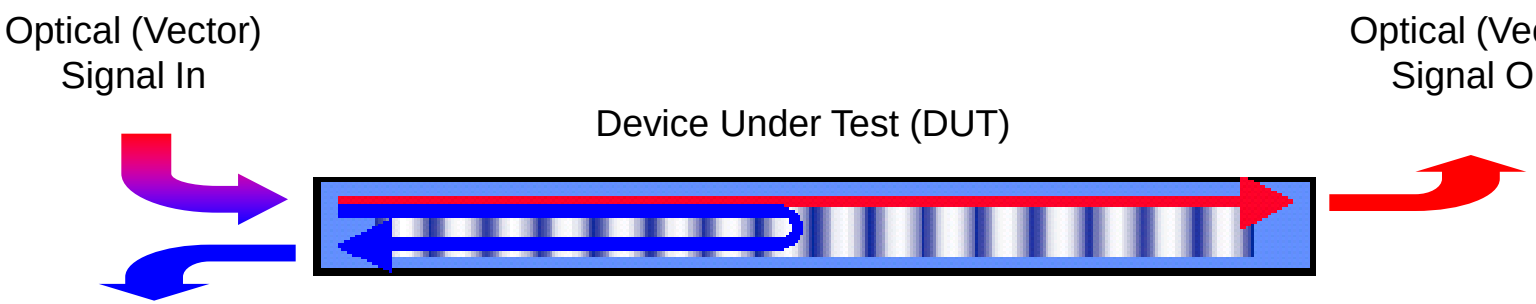
What is an OVA?

Single Connection, Single Scan Yields:

- IL, RL, PDL
- CD, GD, PMD, Second-Order PMD
- Optical Phase Error
- Impulse Response / Time Domain
- Polarization Sensitivity Vs. Wavelength

In Seconds!

What Does the OVA Measure?



$$\begin{bmatrix} E_{x,out}(\omega) \\ E_{y,out}(\omega) \end{bmatrix} = \begin{bmatrix} J_{11}(\omega) & J_{12}(\omega) \\ J_{21}(\omega) & J_{22}(\omega) \end{bmatrix} \begin{bmatrix} E_{x,in}(\omega) \\ E_{y,in}(\omega) \end{bmatrix}$$

DUT is completely characterized by the linear transfer matrix.
From this, calculate IL, PDL, GD, CD, PMD, etc.

How is the OVA Different?

- **Full transfer function measurement**
  - Single scan access to all parameters
  - Fastest measurement time available
- **Interferometric measurement method**
  - Highest available resolution and accuracy and stability
- **Direct optical phase measurement**
  - No reconstruction from group delay, no “phase difference” (e.g. MPI) results
  - Only direct phase measurement technique

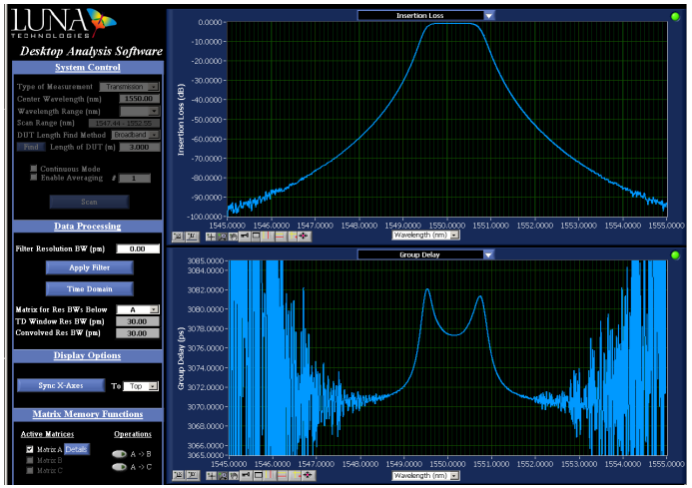
The Result is…

Dramatic design and manufacturing cost reduction through…

- Greatly increased manufacturing throughput
- Reduced design cycles through more comprehensive characterization
- Complete measurement integration
- Ultimate accuracy and resolution
- Ease of use

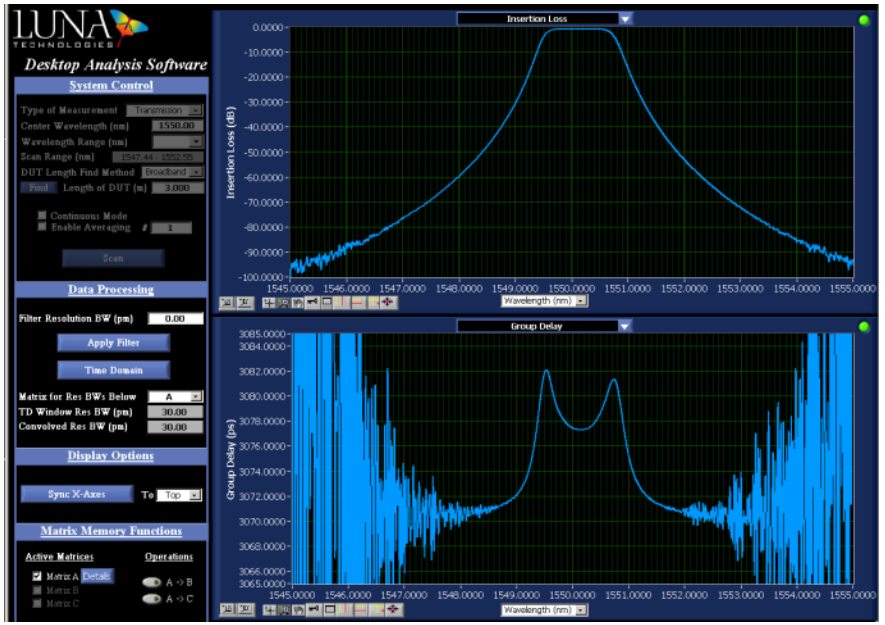
OVA Product Highlights

- **All Parameter Analysis**
  Obtain all parameters in a single scan
- **Exclusive Linear Transfer Function Measurement**
  The most complete measurement of your component available
- **Industry Leading Accuracy**
  Fully specified measurements in < 15 seconds for full wavelength range
- **Breakthrough Measurement Speeds**
  View all parameters in “Real Time” at up to 4 Hz update rates

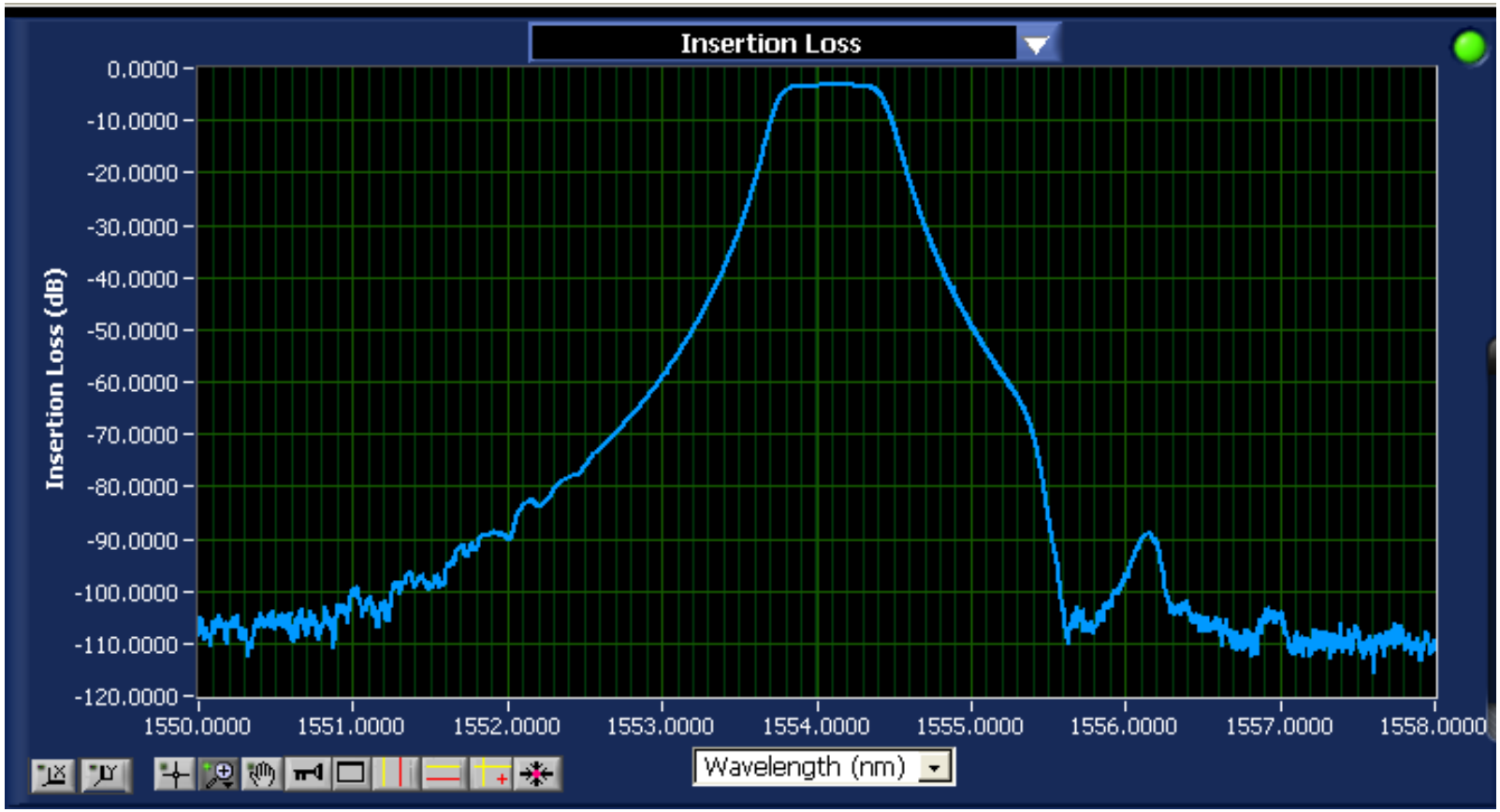


OVA Product Highlights

- **Time Domain Filtering**
  “Look inside” devices with femtosecond resolution
- **Auto Internal Calibration**
  Calibrate once and test for days over +/- 5 °C temperature range
- **Desktop Analysis Software**
  Analyze stored data (No retesting!) at later time and location
- **Future Proof Results**
  Interrogate the LTF and produce any linear parameter
- **Rapidly isolate faults**
  Locate breaks and reflective events



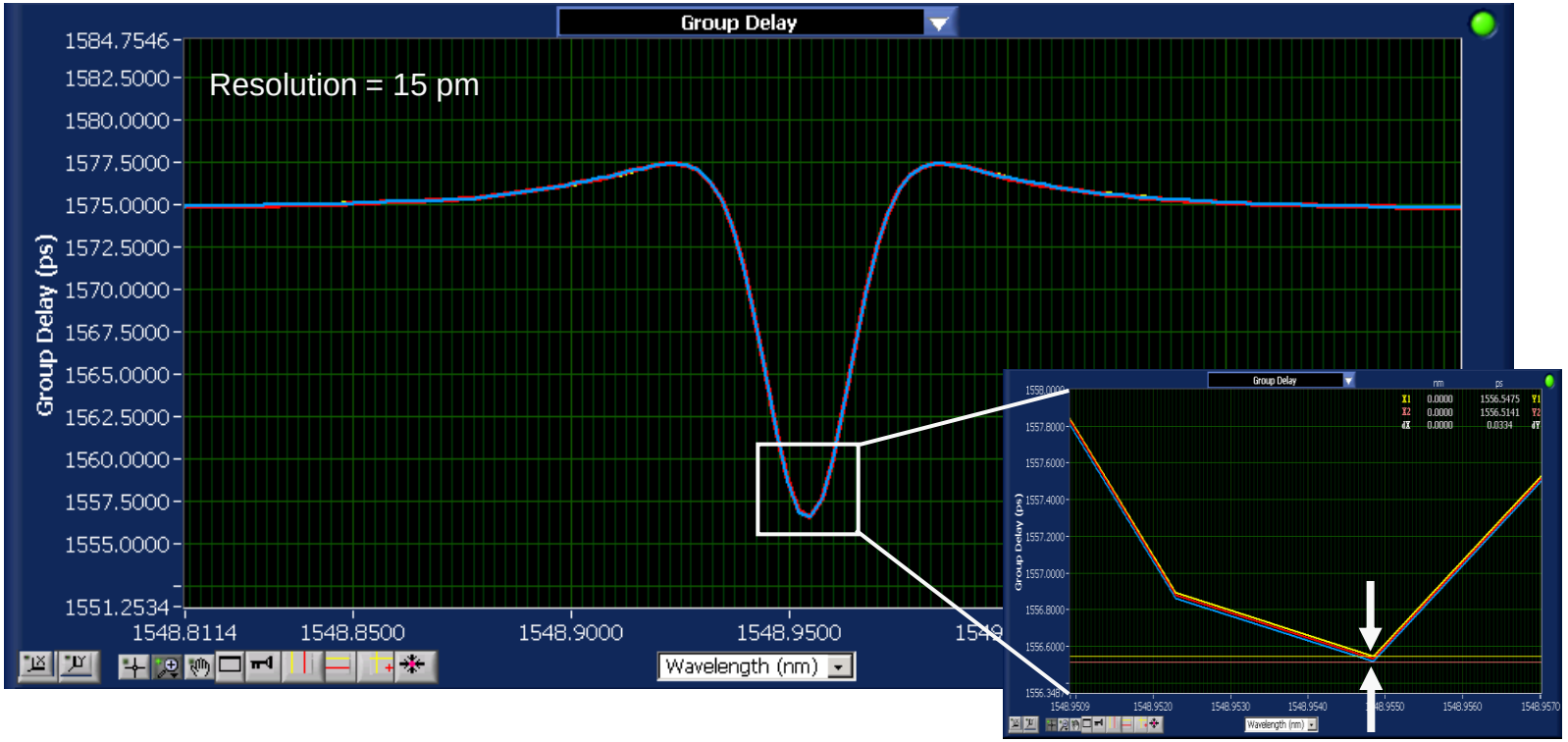
Measurement Example: DWDM Filter



Highest dynamic range available on the market for:

- Loss/PDL
  -100 dB
- PMD
  -50 dB
- Group Delay/CD
  -55 dB

Measurement Example: Gas Cell



OVA measurements provide the ultimate in GD/CD accuracy and resolution

Repeatability < 20 fs
Accuracy = +/-50 fs

OVA 5000 - Overview

New Features

- > Twice the length of the STe (150m)
- Full C+L band scan
- 25% faster over the C+L band
- Reliable USB connection
- Smaller Footprint (notebook) PC

OVA 5000 All Parameter Analyzer

Application Information

- All parameter measurements for:
  - Manufacturing floor
- Longer length modules/assemblies

Benefits & Results

- Longer DUT length:
  - Switch banks
  - Splicing spools
    - Amplifier or longer length modules
  - Smaller footprint:
    - Rack / lab bench space
  - Reliability:
    - USB connection to controller

Competitive Information Pro

Agilent 86038C: Faster, smaller, better specs, less expensive ~ OVA still cannot test long spools of fiber.

Competitive Information Con

OVA CTe: Because of the USB connection, 3 hertz updates in narrow wavelength ranges are not limited to 1 hertz.

Network Analyzers Summary

- Reduce development cycles 60%
- Decrease cost of test 80%
- Perform long-term tests with automatic calibration
- Measure with industry-leading speed and accuracy
- Enhance simulation and modeling packages
- Capture complete optical performance with the linear transfer function.
- Protect investment with Luna’s future-proof design
- Improve functionality

Fiber Optic Switches – FOS Overview

Fiber Optic Switch™ (FOS)

Multi-port Fiber Optic Switch™

Perform high port count optical test and measurements in less time and with fewer costs

- High port count
  *(**1x8** and **1x36** formats)*
- Rapid switching time
- Low insertion loss
- High port-to-port IL uniformity
- Wide wavelength range
- Low wavelength dependent loss

- High performance
- Increased flexibility
- Increased functionality

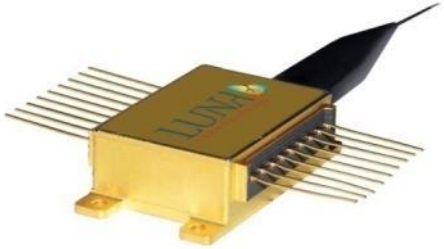
High performance and flexibility at a fraction of the cost.

Laser Sources – PHOENIX Overview

Tunable Laser (PHOENIX™)

High Speed, Tunable Laser

- Fiber Optic Test and Measurement
- Spectroscopy
- Fiber Sensing
- Metrology
- Optical Coherence Tomography

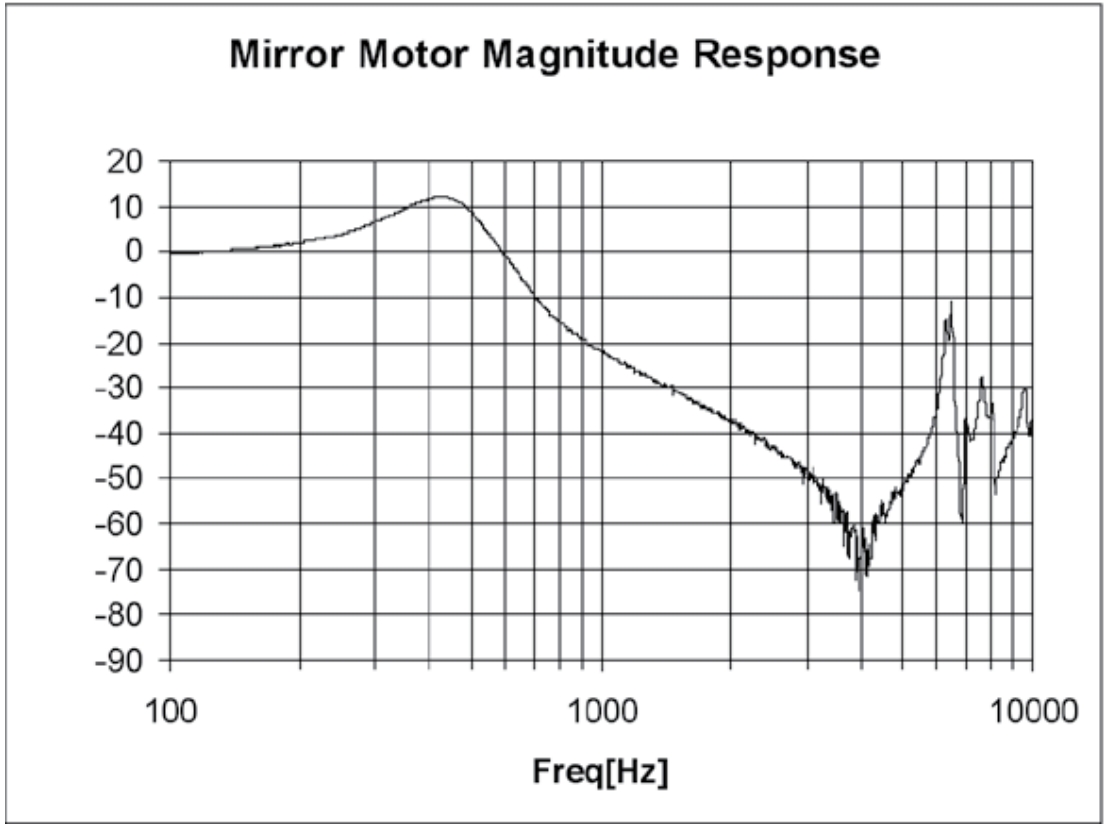


- The performance of the Iolon “Apollo” Laser with improved noise and tuning capabilities
- A small yet rugged design is optimal for mobile applications

Tunable Laser (PHOENIX™)

Features

- Full C-band tunability
- Fast tuning up to 500 Hz
- Rugged design withstands testing rigors
- Narrow linewidth
- Superior noise reduction



Product Recap

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Optical Vector Analyzer™ (OVA)

Reflectometers

Optical Backscatter Reflectometer™ (OBR)

Switches and Laser Sources

PHOENIX 1400

Sensing

Optical Distributed Sensor Interrogator (ODiSI)