Optical Backscatter Reflectometers (OBRs) with Sub-Millimeter Resolution for Latency/Length Measurements, and Short Fiber-Optic Network Diagnosis

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Director, Business Development
April 18, 2023

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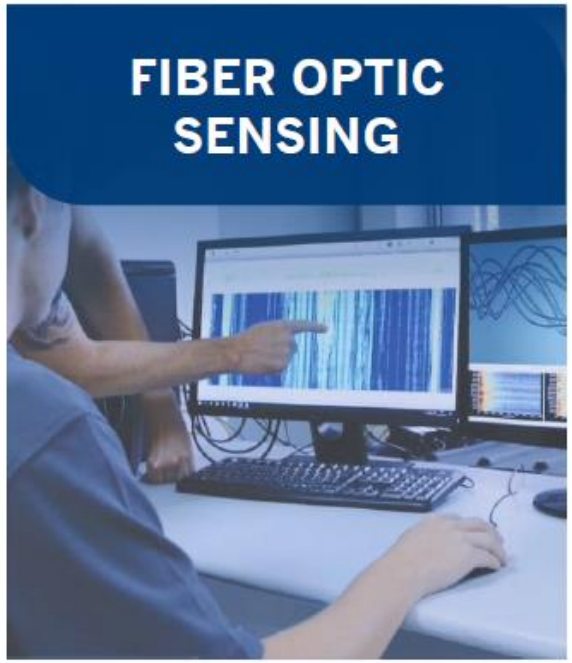
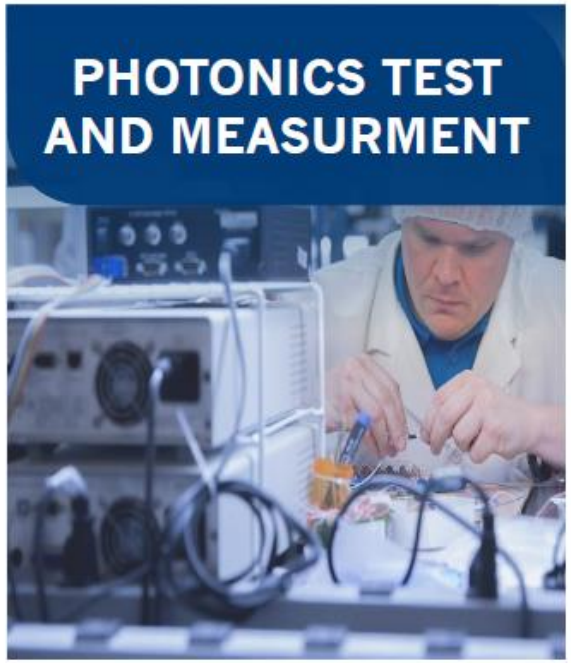
Innovation focus on

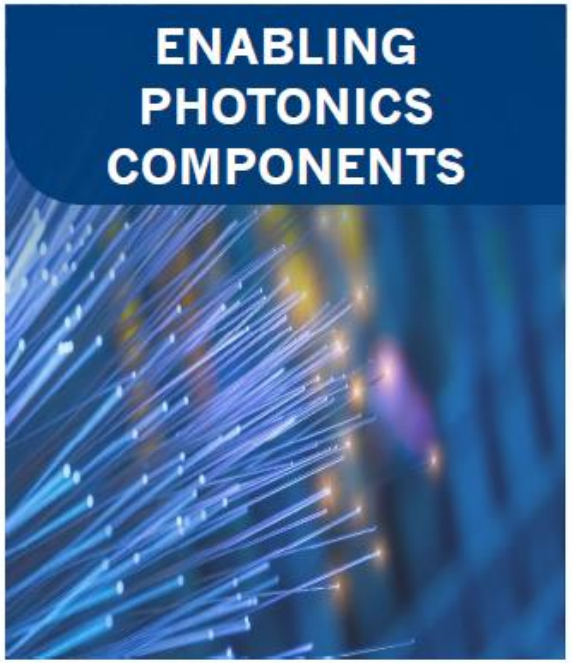
Developing advanced optical technologies for fiber optic sensing and measurement systems, as well as enabling components for a broad range of optical sensing, imaging, and metrology applications.



DAS Rayleigh, DTS-Raman, DTSS- Brillouin, FBG, OFDR



OFDR, Fiber Squeezing, Lithium Niobate, Magneto-optic Crystals



Lasers, Polarization control, Delay Control, Detectors, Coils

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Product examples – Equipment and Components

Fiber Optic Sensing & NDT

Fiber Optic Sensing - Interrogators


ODiSI


HYPERION


OptaSense - DAS


LIOS - DTS

Fiber Optic Sensors


Sensors - Strain, Temperature, Acceleration, Displacement, etc.

Terahertz Gauging and Imaging


T-Ray Control Units


Sensors and Gauges

Photonics Test & Control

Test and Measurement Instruments


Component Analyzer 6415


OVA 5100


Optical Backscatter Reflectometers (OBRs)


Polarization Measurement and Control

Photonics OEM: Lasers, Modules, and Components


Lasers | Filters | Polarization | Delay Lines | Detectors | Fiber Coils

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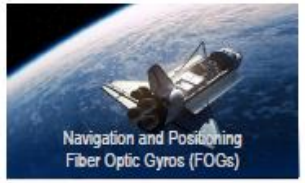
Photonics Test & Control Markets

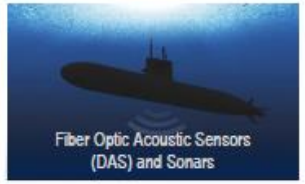
Test & Measurement

Test instrumentation and solutions to characterize and test photonic components

OEM Optical Modules

Technology building blocks integrated into photonic (laser-based) systems





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Photonics Test & Control Markets

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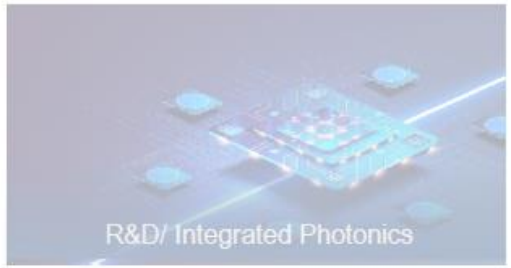
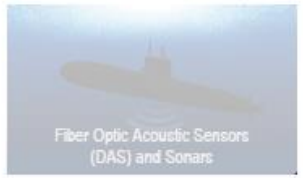


OEM Optical Modules

Technology building blocks integrated into photonic (laser-based) systems



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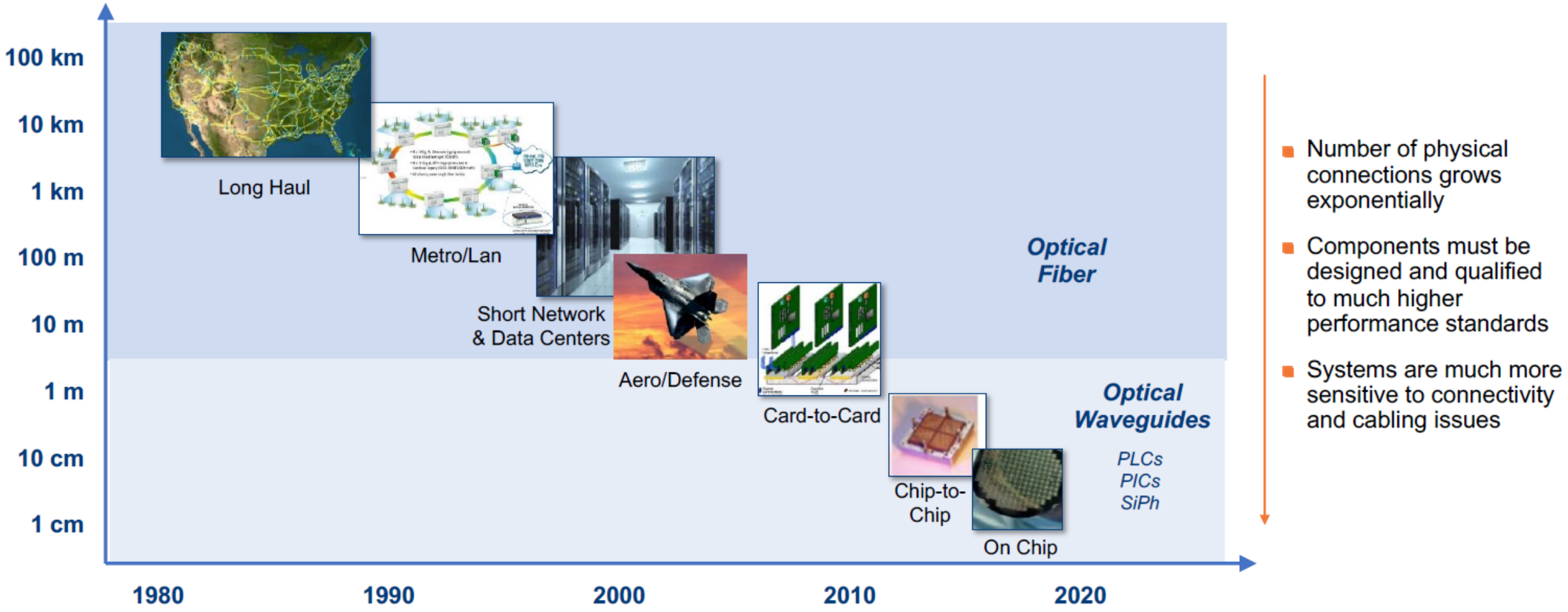
Optical Connectivity Evolution



- Number of physical connections grows exponentially
- Components must be designed and qualified to much higher performance standards
- Systems are much more sensitive to connectivity and cabling issues

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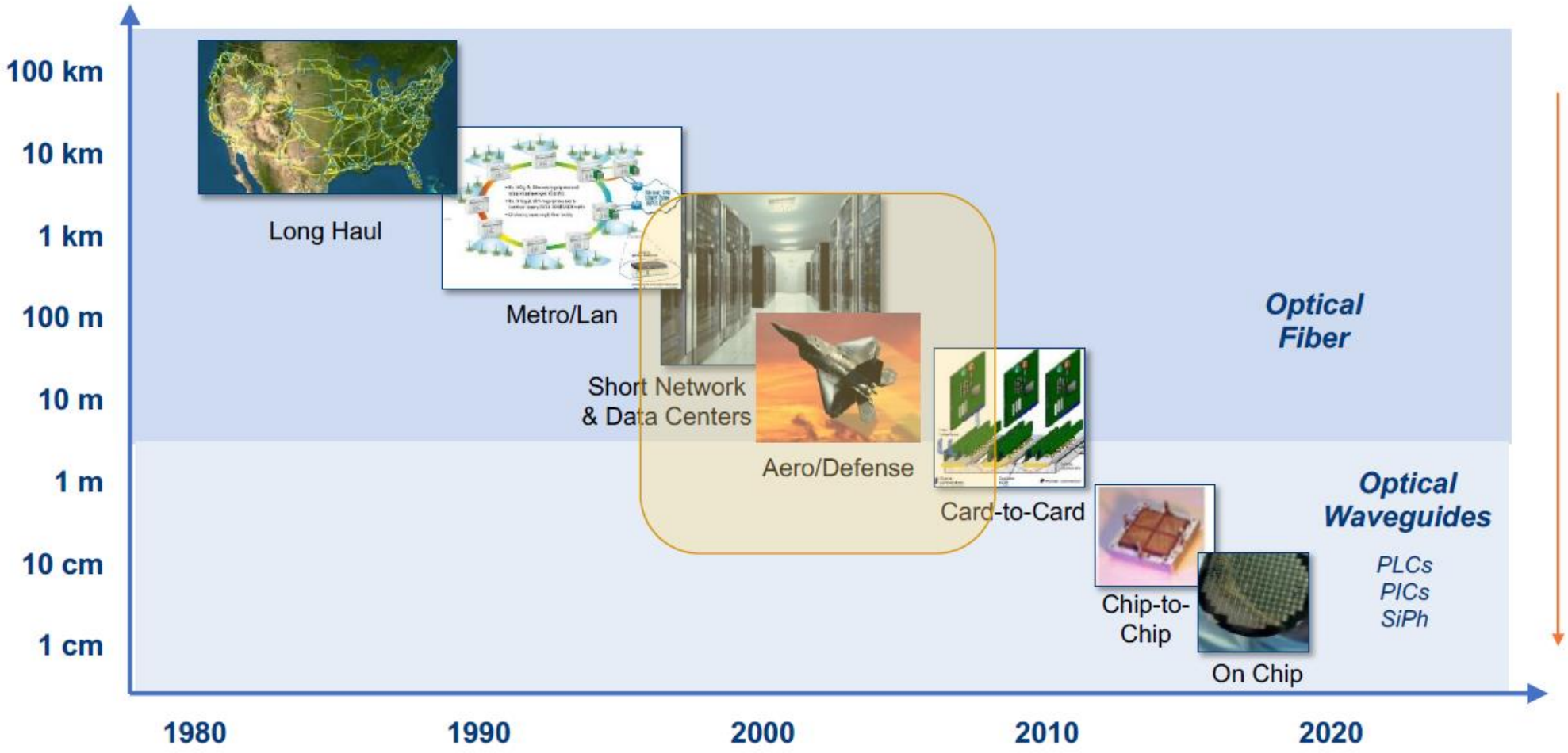
Optical Connectivity Evolution



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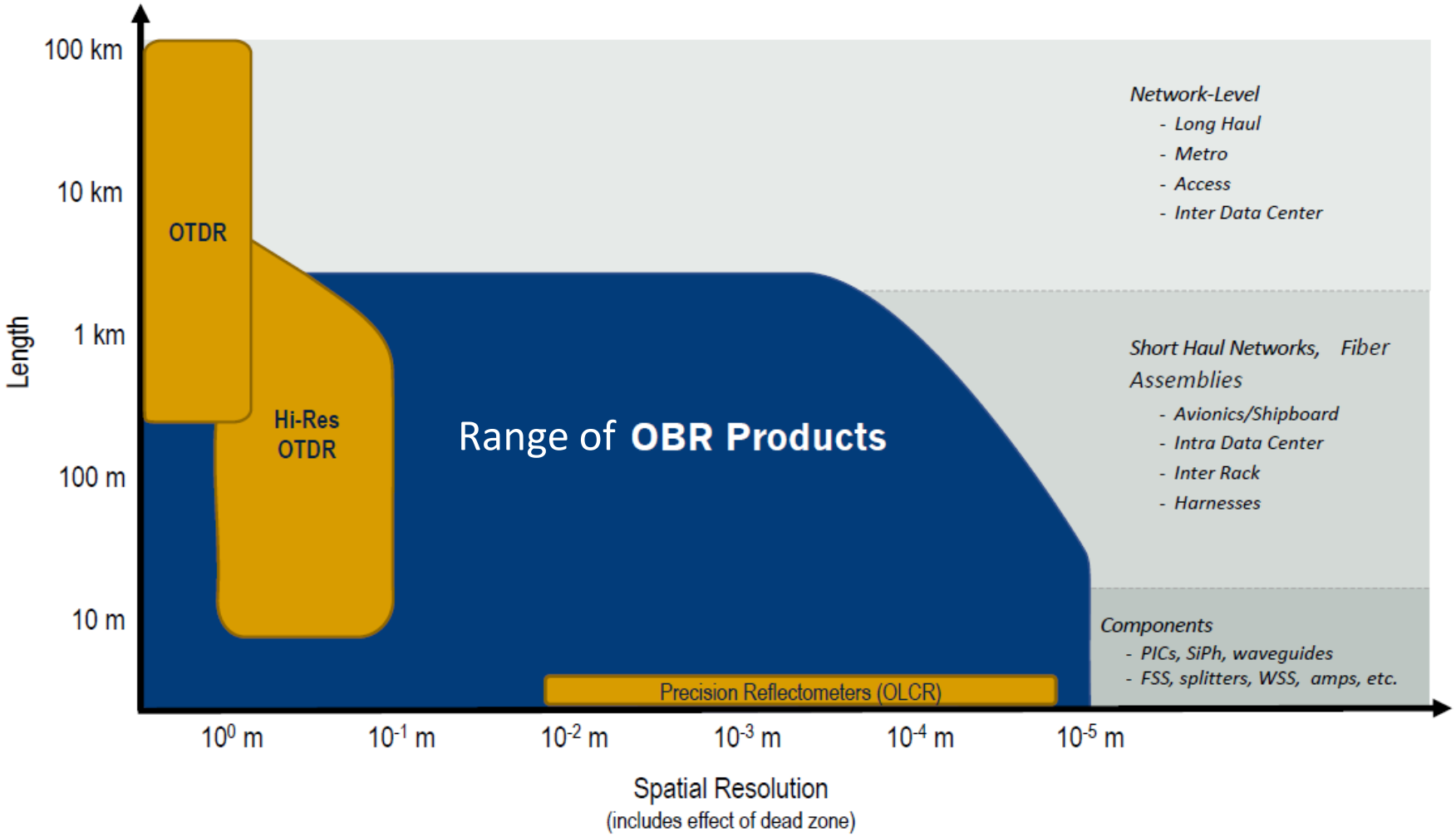
Reflectometry Technologies

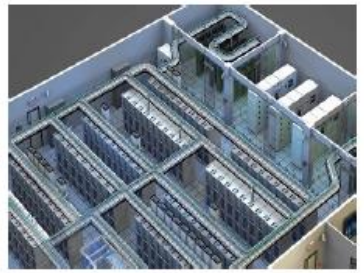


Deploying and Maintaining Short Fiber-Optic Networks

- Installation and Commissioning
  - Proper installation
  - Splice and connector quality
  - Total loss budget
- Length/Latency Test and Control
  - Fiber length control
  - Accurate delay test
- Maintenance – Identify and Locate Issues
  - Fiber breaks
  - Faulty connectors
  - Pinched/bent fiber

◆ Tight Length Tolerance ◆ Higher Density ◆ More Complexity

◆ Difficult Environments and Access ◆ Costly Downtime



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Example: Fiber Optic Assemblies in Aviation

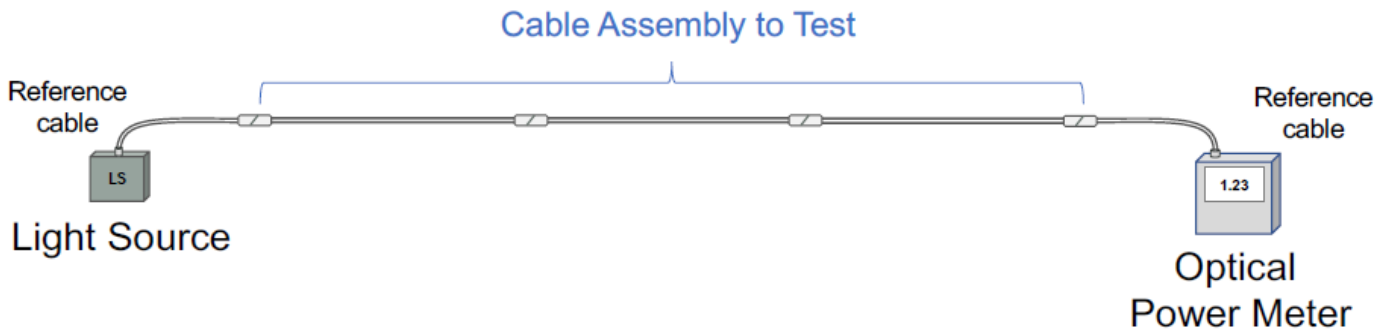
- Short lengths (< 100 m)
- Multiple sections
  - Sections/links can be < 1m
- Restricted access to network
- Expensive downtime
- Harsh environmental conditions

- Test and diagnostics
  - Single access
  - Fast and precise identification
  - Minimize ground time

Testing Fiber Optic Assemblies

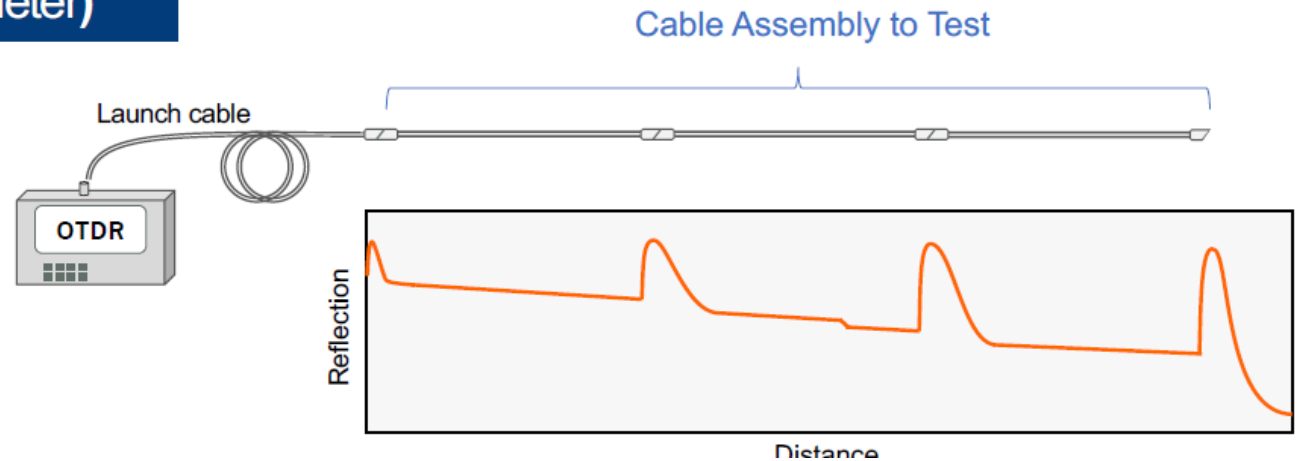
Optical Loss Test Set

- Measure total loss (IL)
- Access both ends of network
- No fault location information



OTDR (Optical Time Domain Reflectometer)

- Single-ended access
- Locate reflections and loss along assembly
- Able to map out km's of fiber optic network
  - Limited spatial resolution



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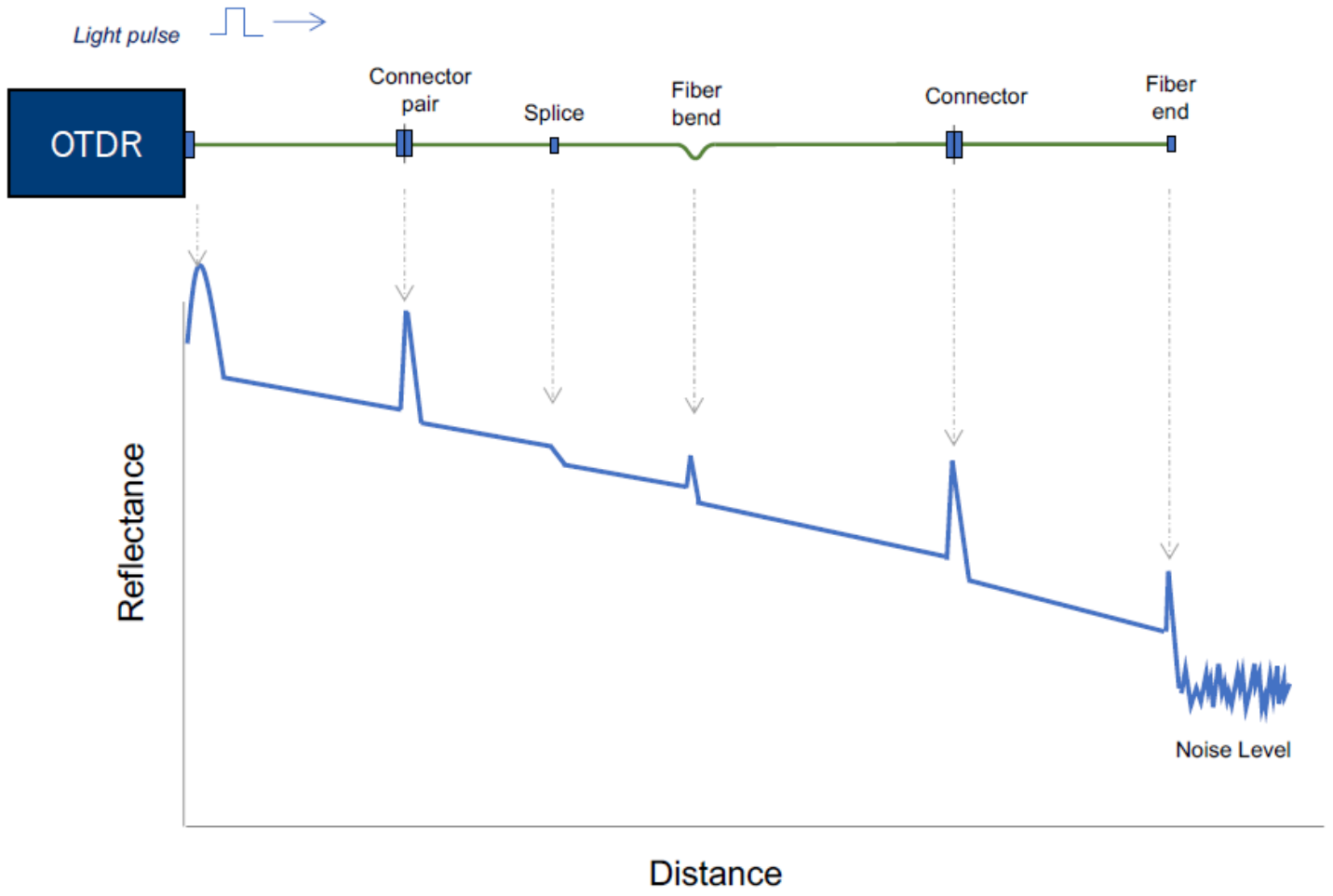
Optical Time Domain Reflectometry (OTDR)



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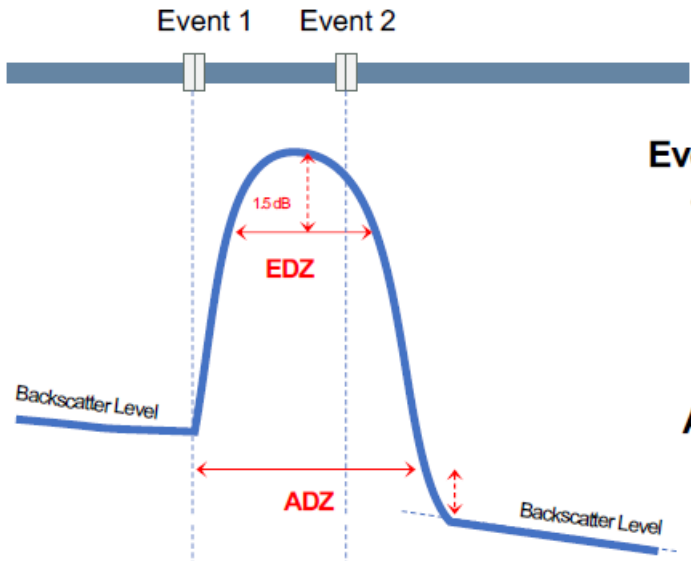
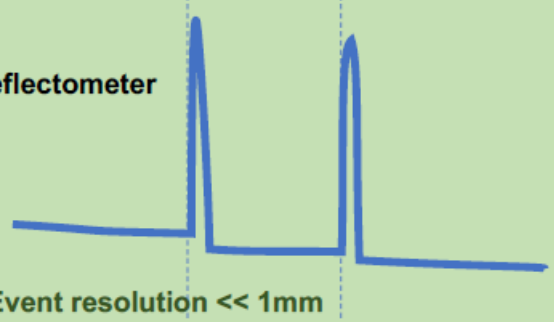
Optical Time Domain Reflectometry (OTDR)

OTDR:



OBR:
Optical Backscatter Reflectometer



Event Dead Zone (EDZ)

- Indicates minimum distance that two consecutive reflective events can be distinguished (not necessarily measured)
- Defined as width 1.5 dB down from reflective peak

Attenuation Dead Zone (ADZ)

- Indicates minimum distance after a reflection where loss can be accurately measured
- Determine by distance needed for trace to return to within 0.5 dB of backscatter level

Typical minimum OTDR dead zones (best conditions):

- Standard OTDRs: ~ 1 – 2 m (or more)

- Specialty high-resolution OTDRs: ~20 – 40 cm

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OBR Technology and Solutions

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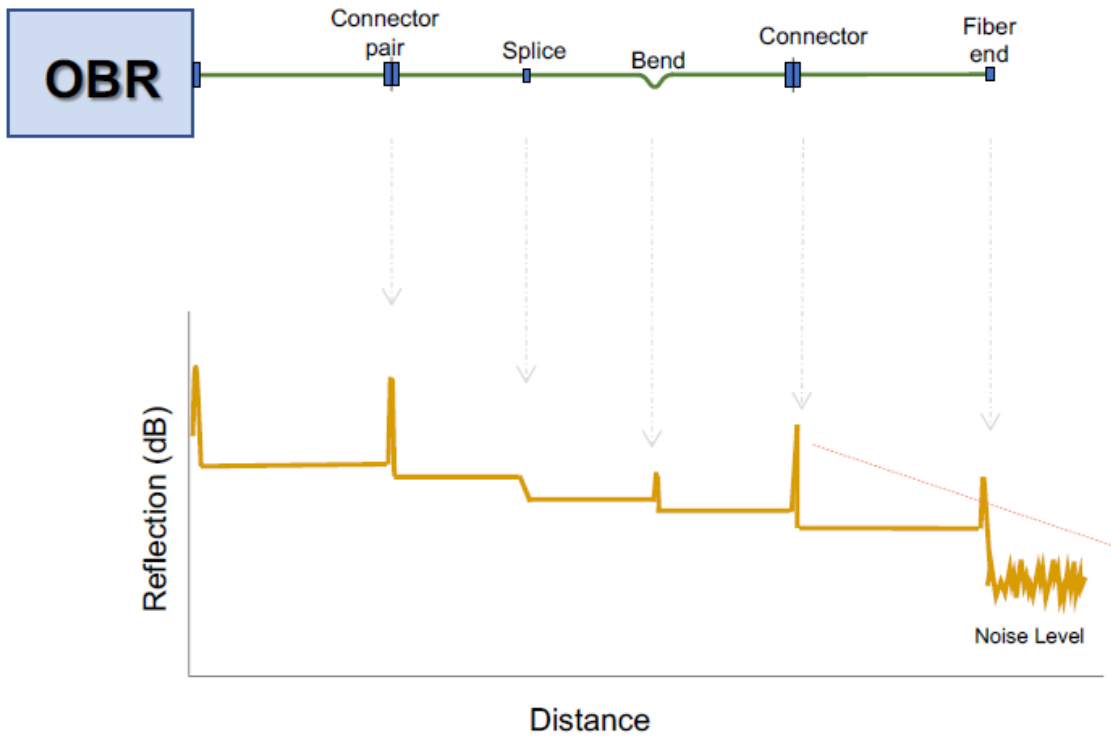
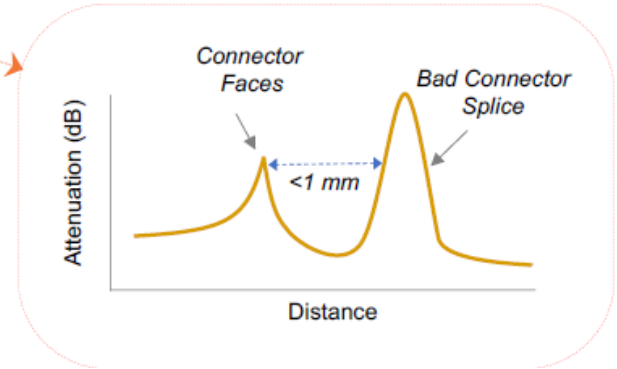
What is Optical Backscatter Reflectometry (OBR)?



- ✓ Measures distributed reflectance as a function of length
- ✓ Ultra-high resolution ~ 10 um
- ✓ No dead zones, and no launch cable
- ✓ Backscatter sensitivity ~ -135 dB
- ✓ Identify reflection and loss events, bends, breaks, splices…
- ✓ High-precision latency measurements with absolute accuracy of ~ <0.0034%
- ✓ Certify lengths with unprecedented accuracy for latency verification

ZOOM



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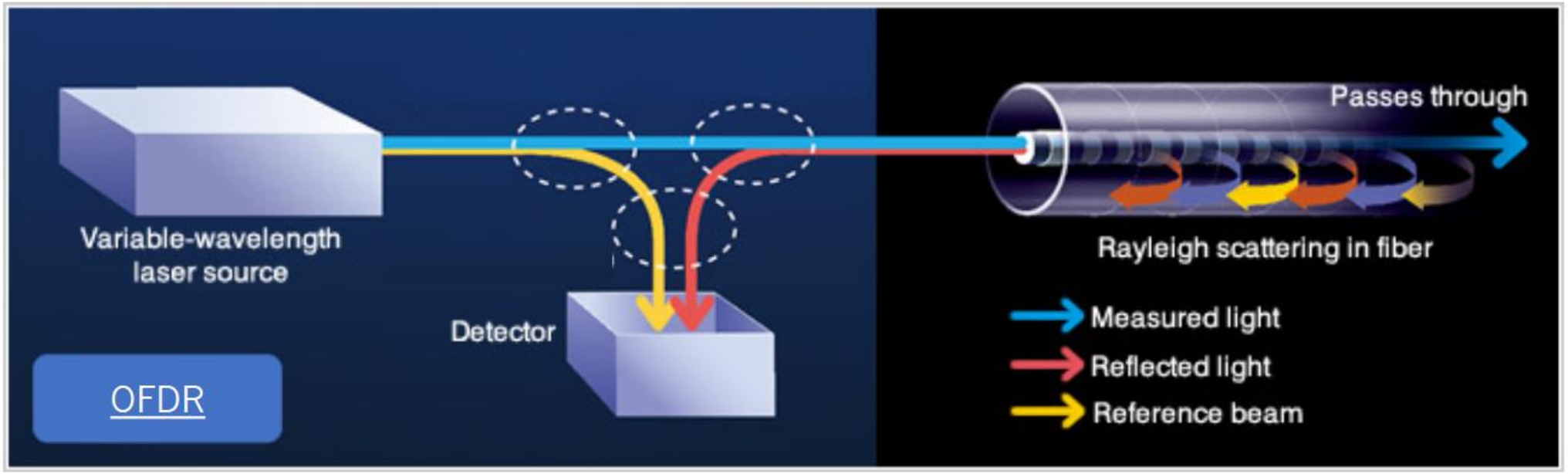
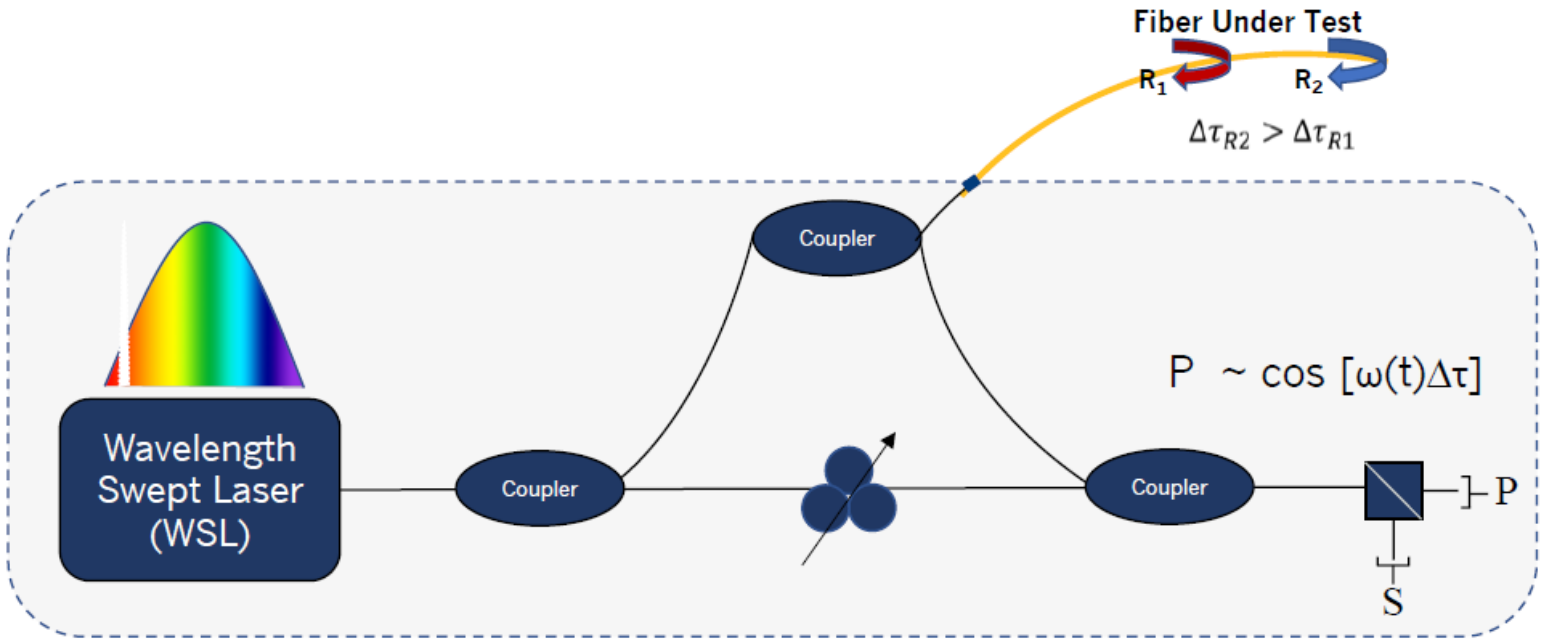
Core Technology Overview

- Lightwave's platform technology, Optical Frequency Domain Reflectometry (OFDR), is the foundation of all products
- Employs coherent, swept laser interferometry to provide the highest levels of accuracy, sensitivity and resolution available
- Significant core-IP developed around laser control, signal and data processing

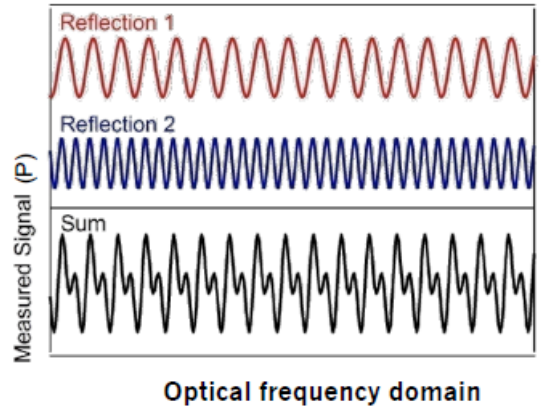


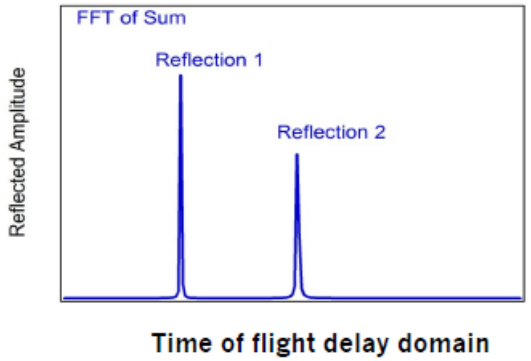
How Does OFDR Work?

- OBR is polarization-diverse implementation of OFDR that further improves the sensitivity and resolution without sacrificing the usable measurement range.



Where: $\Delta\tau$ path delay difference
ω optical frequency

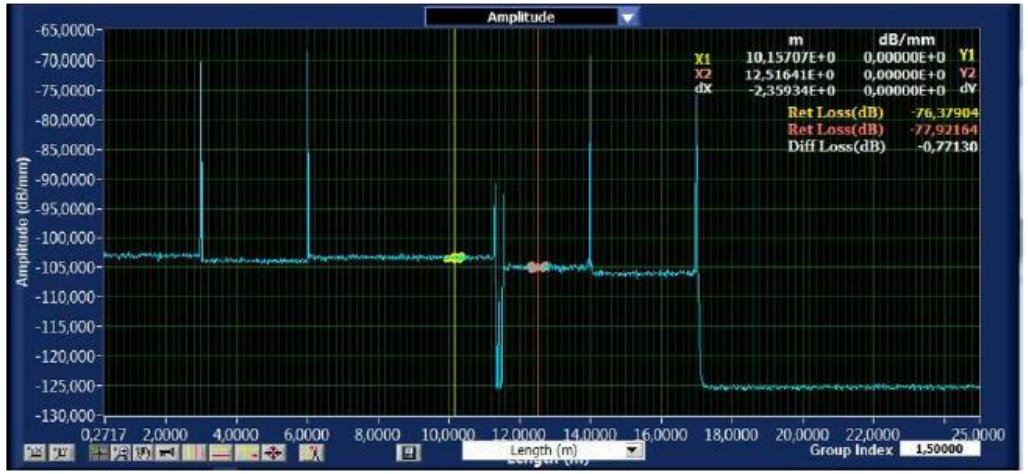




Optical Backscatter Reflectometer

High resolution detection and analysis of events in fiber optic networks and components

- Insertion Loss (IL)
- Return Loss (RL)
- Distributed IL/RL
- Length/delay
- Group delay
- Phase derivative
- Evolution of polarization states
- Spectral analysis



See inside components and networks with micrometer resolution and extremely low noise floor.

- 10 micron spatial resolution (in fiber), -130 dB noise floor and 80 dB dynamic range offer extraordinary visibility inside ultra miniaturized components.
- Dual graphs can display up to four traces. The lower graph can display in time domain and frequency domain.

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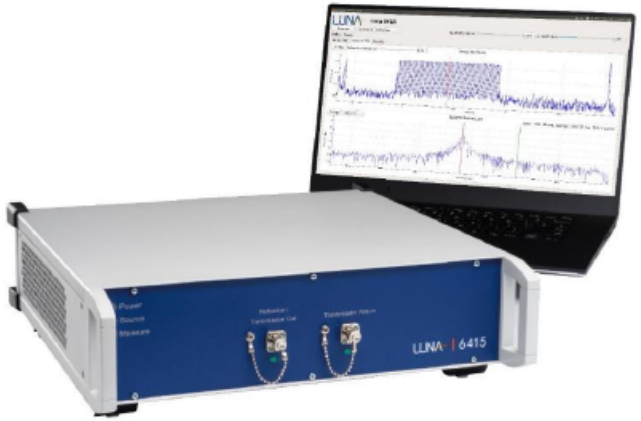
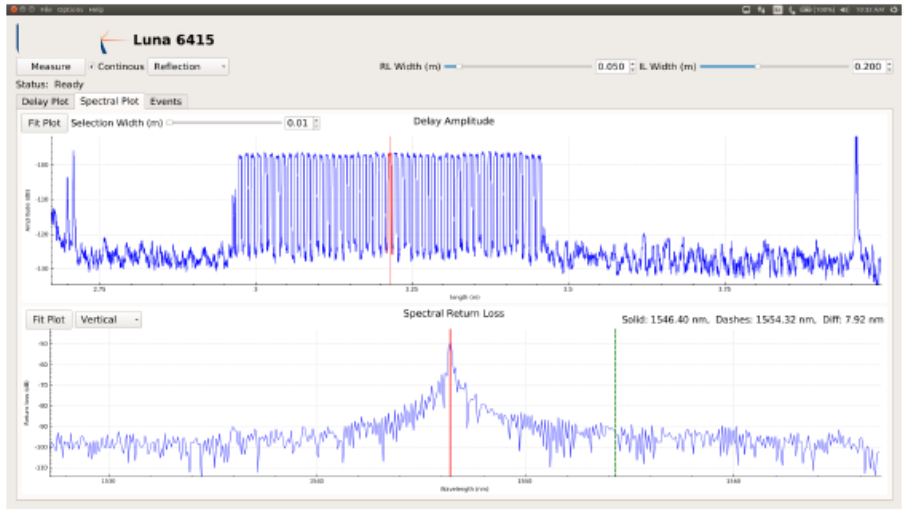
Lightwave Distributed Component Analyzer





Fat and high-resolution distributed component analyzer that characterized loss in reflection or transmission

- Insertion Loss (IL)
- Return Loss (RL)
- Distributed IL/RL
- Length/delay
- Spectral analysis
- Transmission loss spectra

See inside components and networks with micrometer resolution and extremely low noise floor.

- 20 micron spatial resolution (in fiber), -130 dB noise floor and 70 dB dynamic range offer a fast and simple to-use tool for testing passive optical components and fiber optic networks
- Dual graphs can display up to four traces. The lower graph displays the frequency domain.

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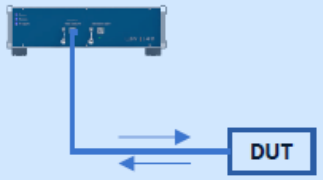
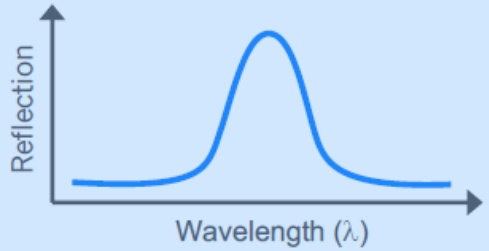
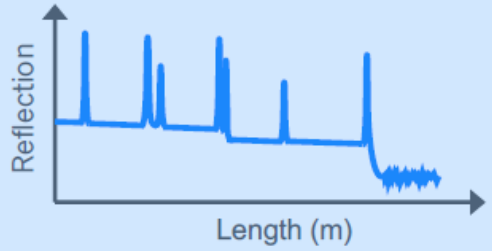
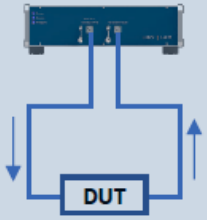
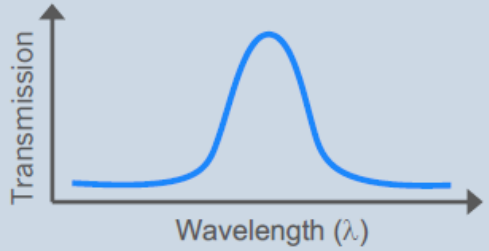
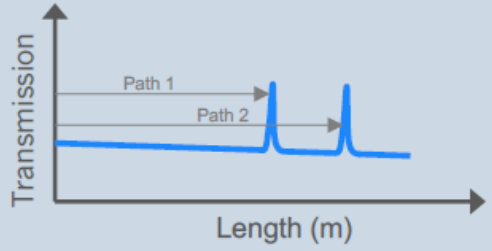
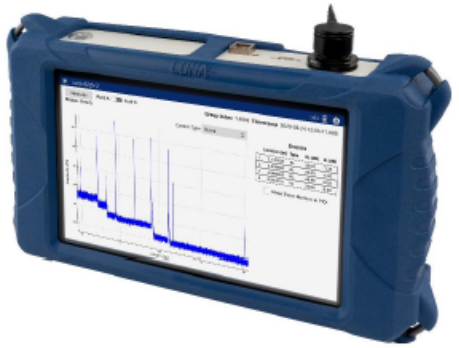
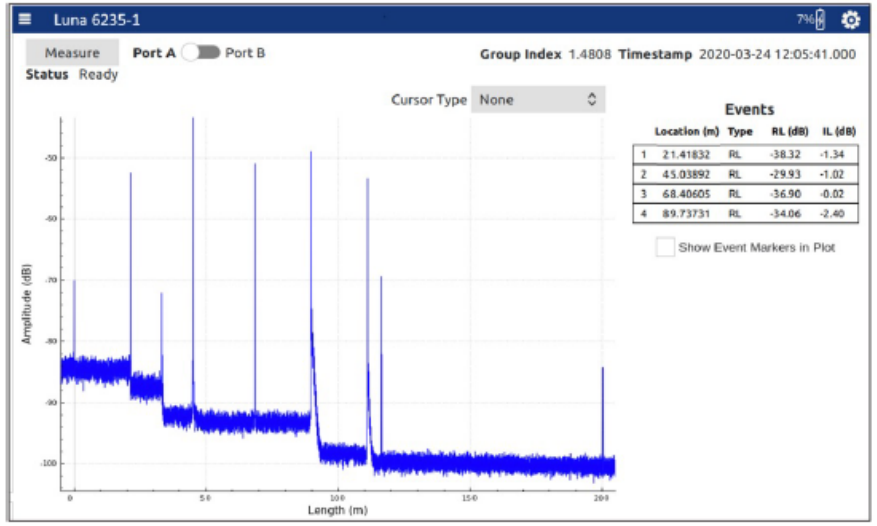
Complete Solution for Characterizing Optical Components, Including Waveguide Structures

	Spectral Analysis	Time Domain Analysis
Refection Measurements 	• RL spectrum – overall • RL spectrum – at specific location 	• RL and IL versus length • Event detection and location • Event length measurement 
Transmission Measurements 	• Transmission spectrum • IL measurement 	• Total IL measurement • Total path length measurement 

Portable Optical Backscatter Reflectometer





High resolution detection and analysis of events in fiber optic networks and components

- Insertion Loss (IL)
- Return Loss (RL)
- Distributed IL/RL
- Length/delay

See inside components and networks with micrometer resolution and extremely low noise floor.

- Down to 80 micron spatial resolution (in fiber), -129 dB noise floor, and 70 dB dynamic range offer an easy tool for troubleshooting and diagnosing fiber optic assemblies with extremely high precision
- Quickly measure *distributed* RL, IL, and latency with high precision
- Easy-to-use touchscreen GUI

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Comparison between OFDR-Based Reflectometer

		OBR 6200 Series	Luna 6400 Series	OBR 4600 Series
Wavelength band		C	C	C/L, O
Reflection	Delay domain (RL vs length)	✔	✔	✔
	Spectral analysis	-	✔	✔
	Scatter level sensitivity	✔	✔	✔
	Max Measurement length Modes	6225: 100 m 6225 with extended Length: 200 m 6235: 200 m 6235 with extended Length: 500 m	6415: 20m, 50m, 100m 6415 with extended Length: 200 m 6435: 200 m 6435 with extended Length: 500 m	30m/70 m/2 km
Transmission	Loss analysis	-	✔	-
	Measurement length Modes	-	6415: 40m, 100 m, 200m 6415 with extended Length: 400 m 6435: 400 m 6435 with extended Length: 1000 m	-
High-Speed		-	✔ **12 Hz**	-
Polarization measurements		-		Track polarization states
Phase measurements		-		Group delay, phase derivative
Distributed sensing option		-		✔
Sampling Resolution (Reflection Mode)		80um @ 20m, 0.1mm @ 50m 0.2mm @ 100m, 0.4mm @ 200m 1mm @ 500m	20um @ 200m 80um @ 500m	10um @ 30m 20um @ 70m 1mm @ 2km

Testing Results

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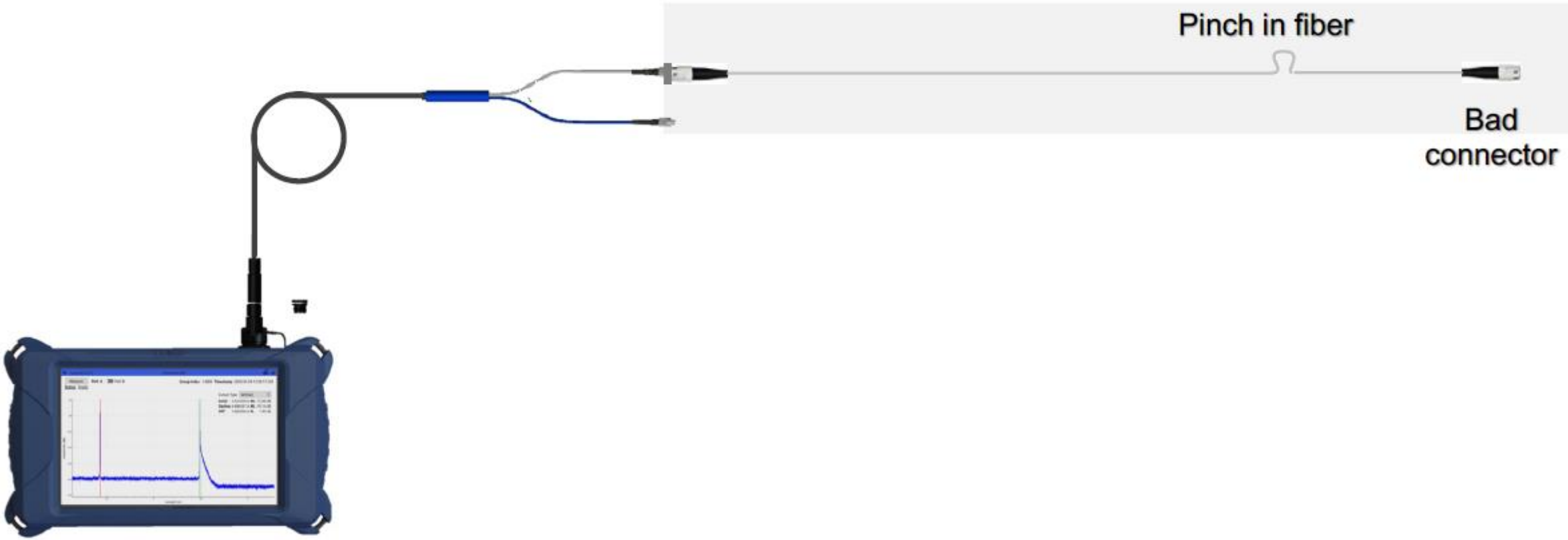
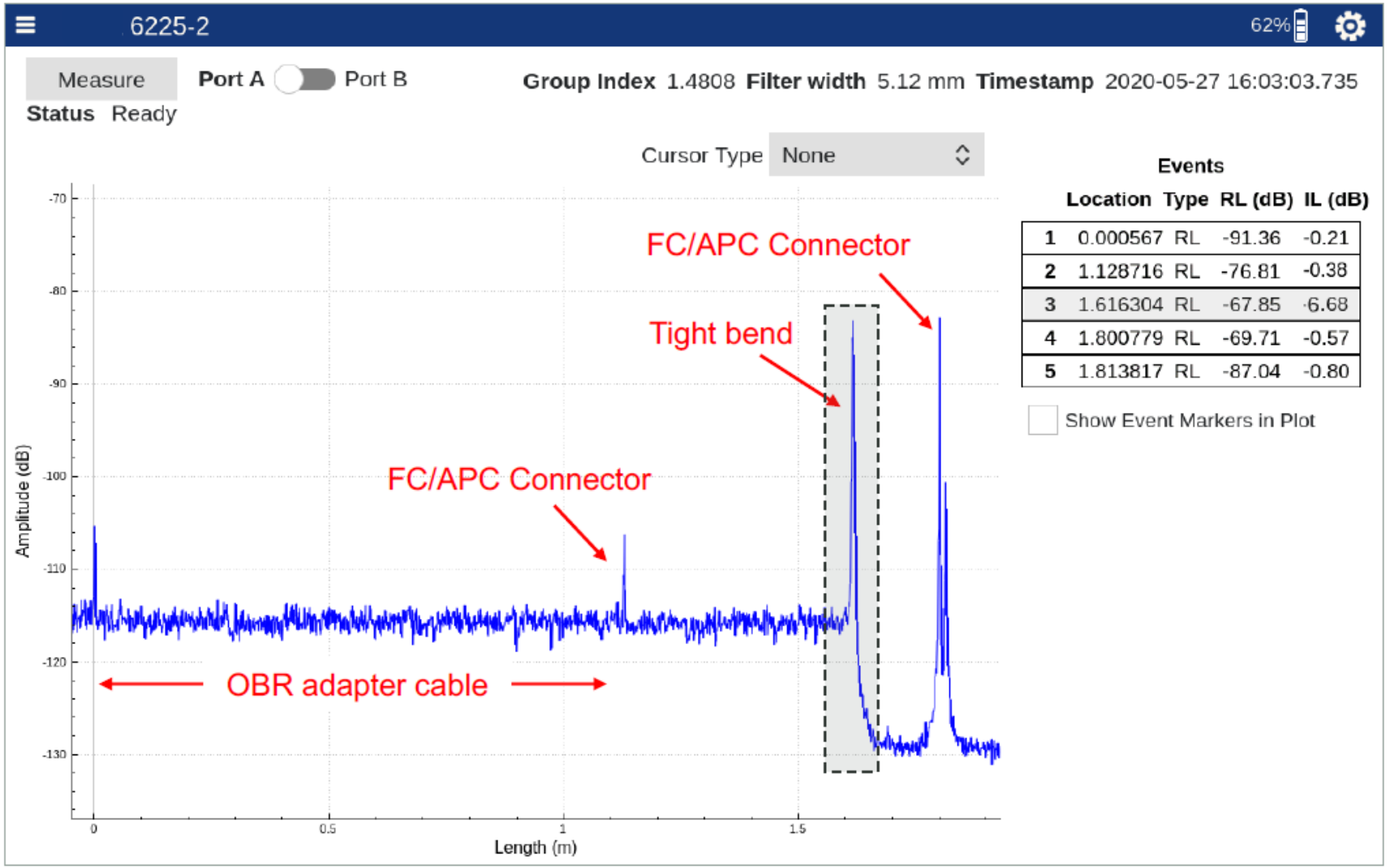
Measurement Example: Short SMF Jumper Cable



Measurement Example: Short Jumper Cable



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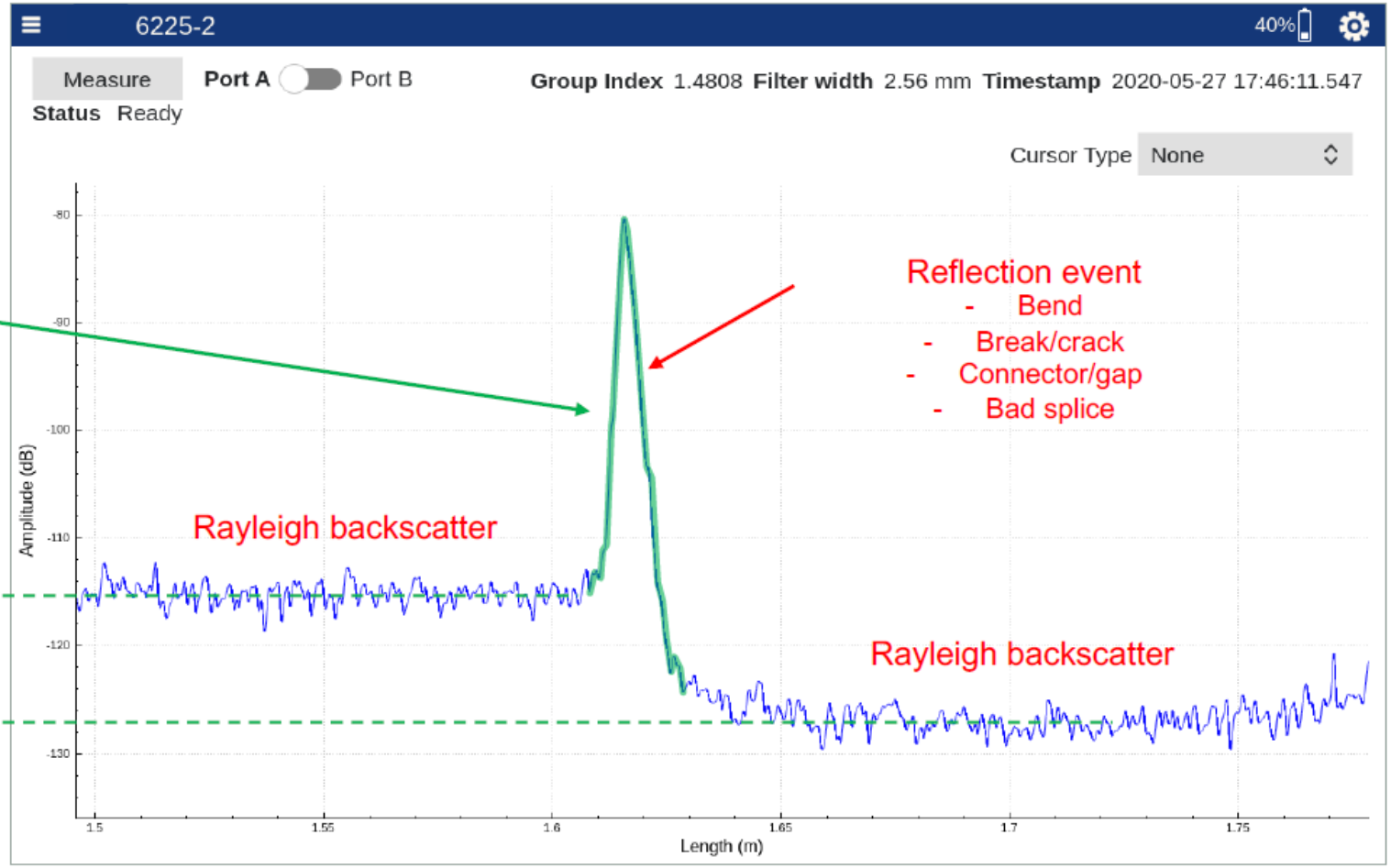
Measuring RL and IL

RL at a location is integration of reflectance over that area

IL (loss) measured by decrease in backscatter levels



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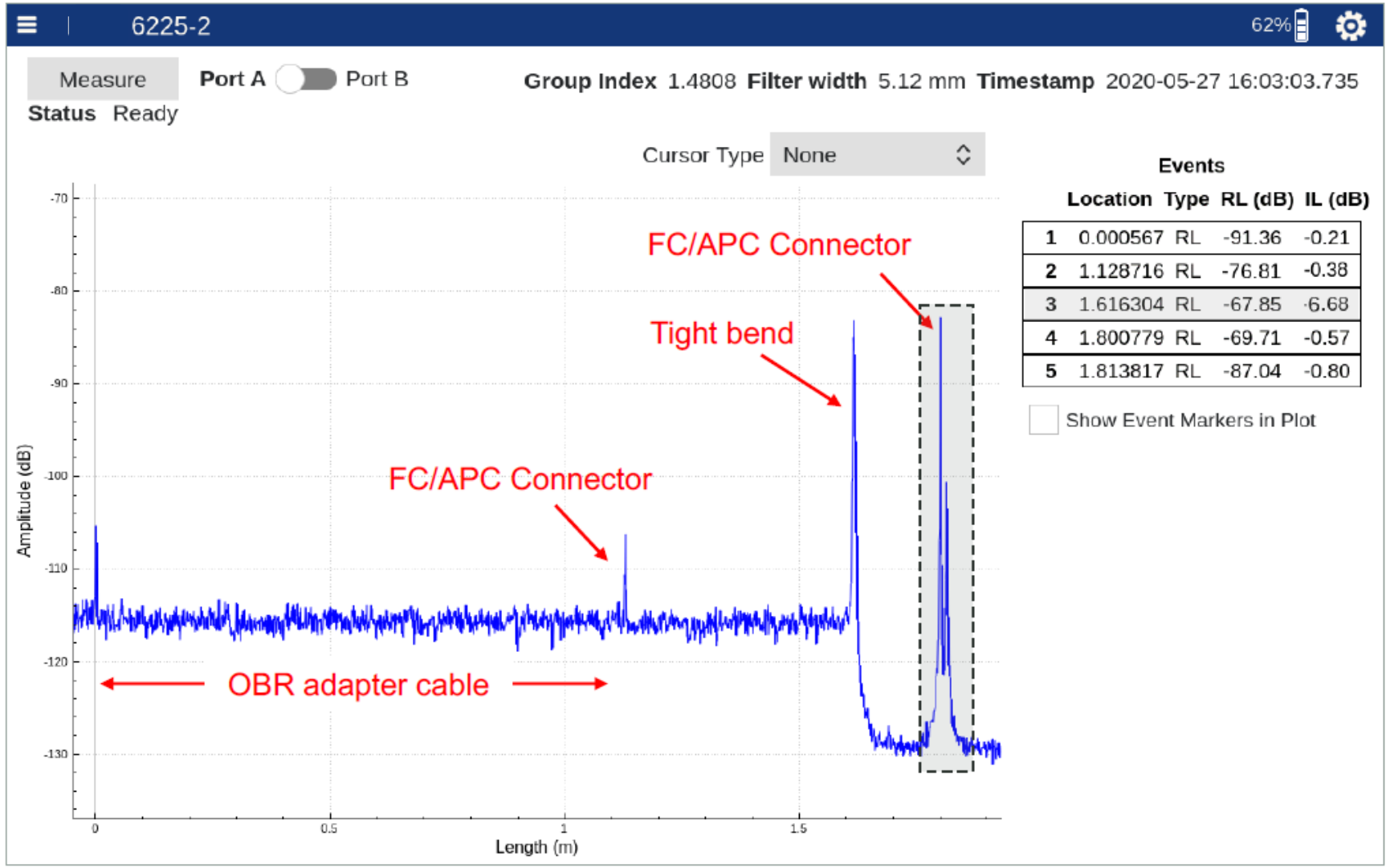
Measurement Example: Short Jumper Cable



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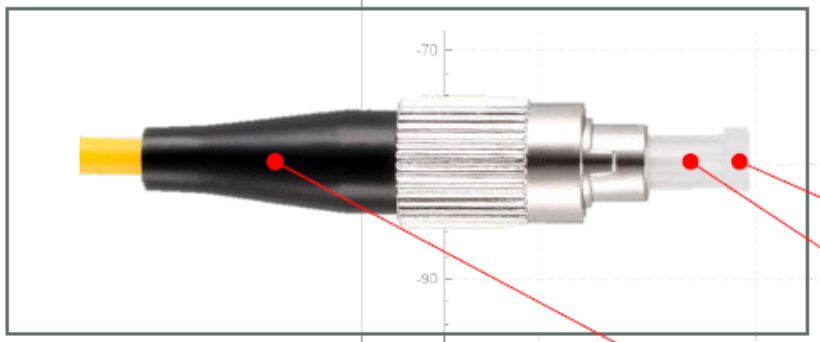
Distinguishing Reflections



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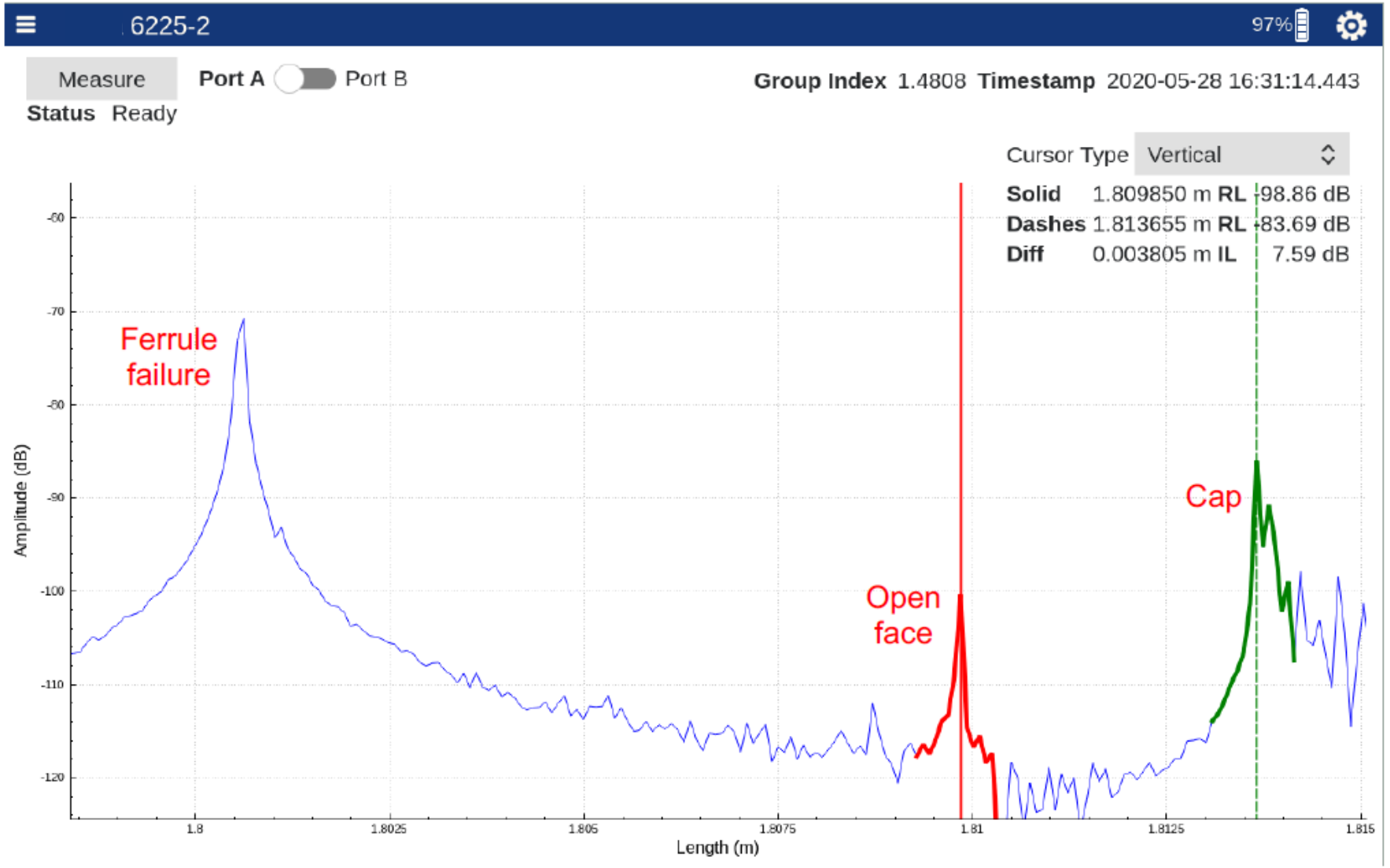
Distinguishing Reflections



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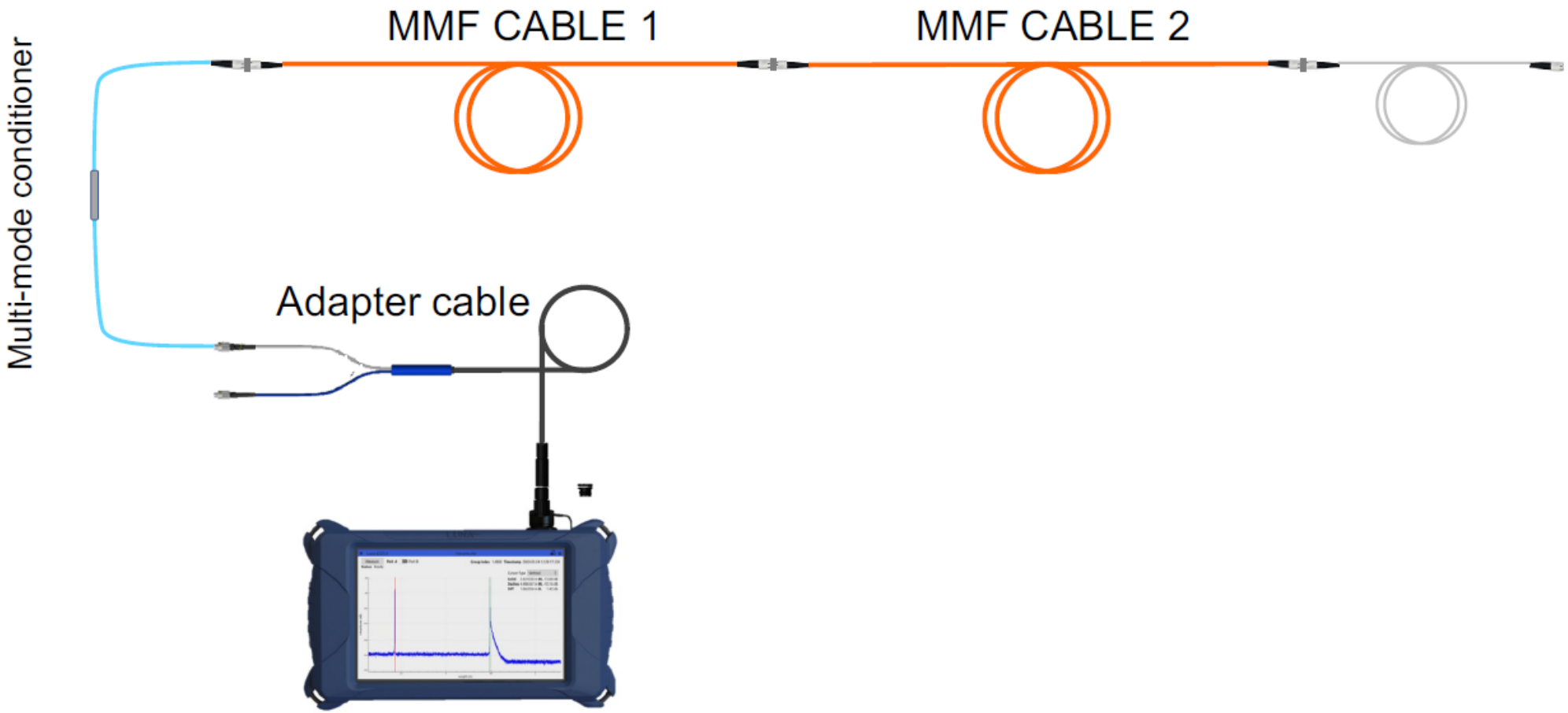
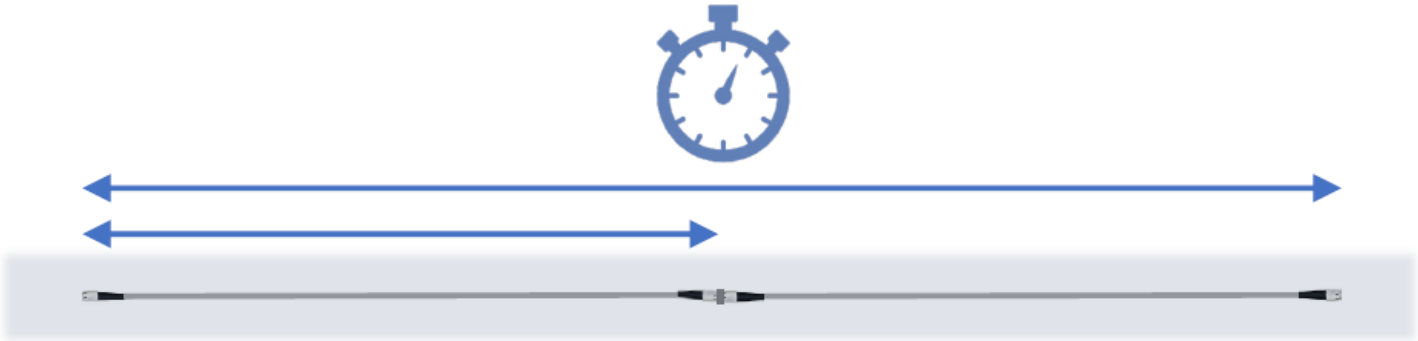
Demonstration of Portable OBR



Using OBR to Measure Latency and Skew



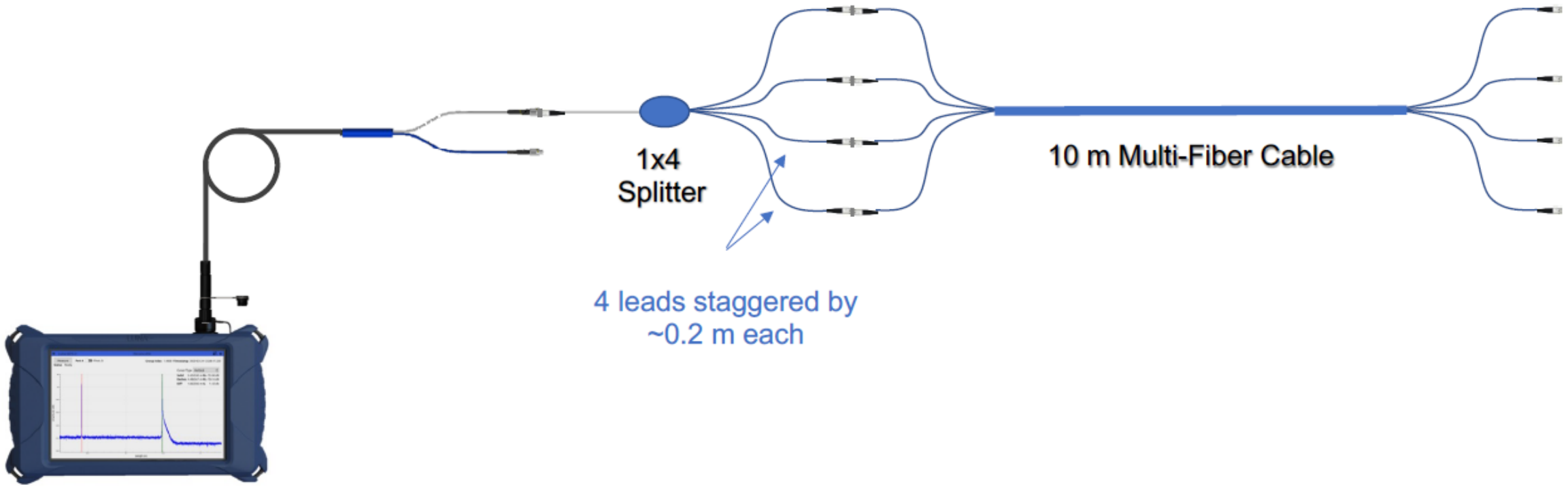
Measure fiber skew/latency with ultra-high accuracy and precision

- Financial trading latency certification
- Manufacturing quality control
- Delay lines
- Phased array radar

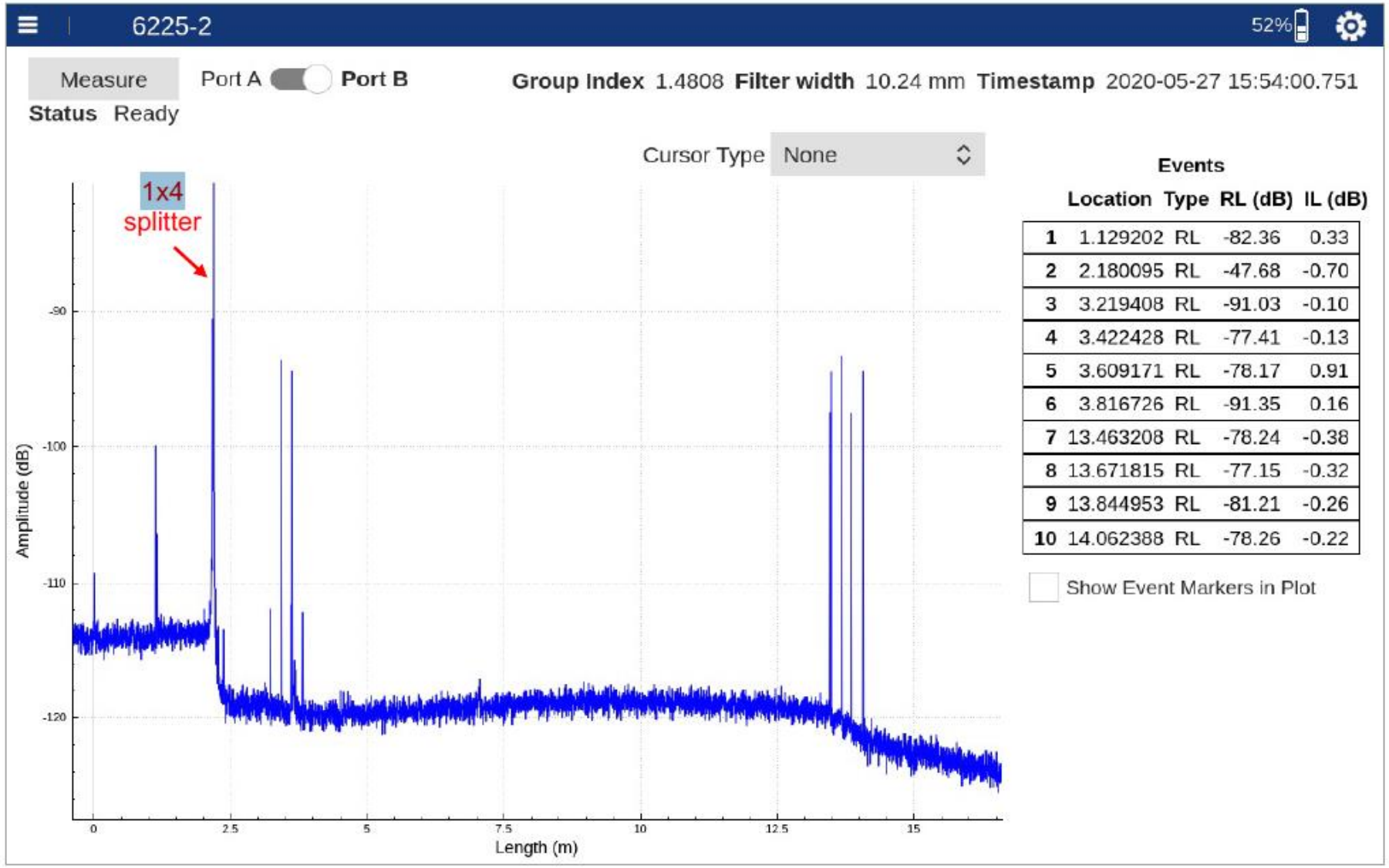
Latency Measurement Accuracy
OBR 6225

	Measurement Accuracy	
	Length	Latency
20 m	<1 mm	< 0.005 ns
50 m	<2 mm	< 0.010 ns
100 m	< 4mm	< 0.020 ns

Measurement Example: Cable Skew/Latency Measurement



screenshots



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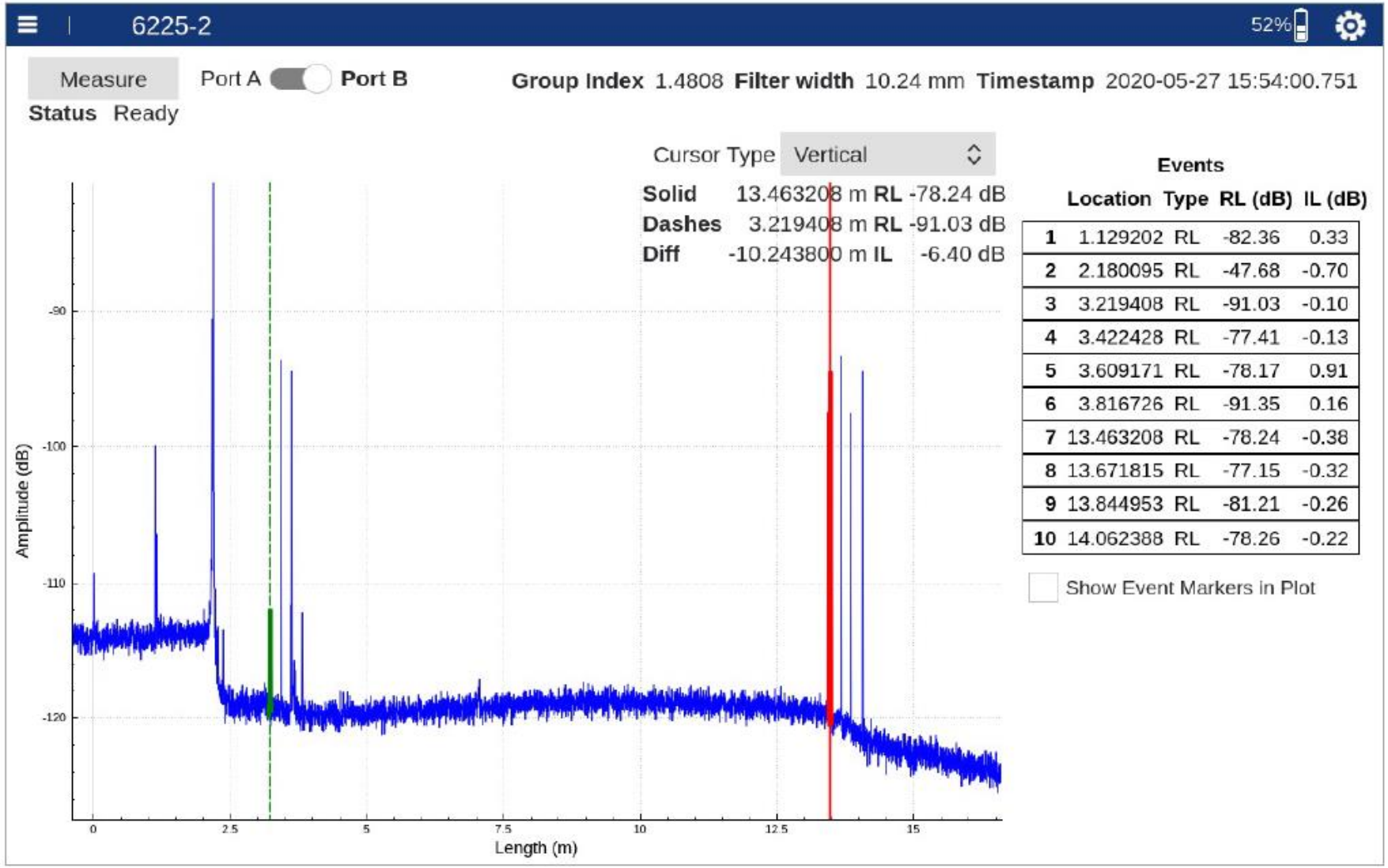
Screenshots



Fiber Lengths (m):	
Fiber 1	10.2438
Fiber 2	10.2494
Fiber 3	10.2358
Fiber 4	10.2457

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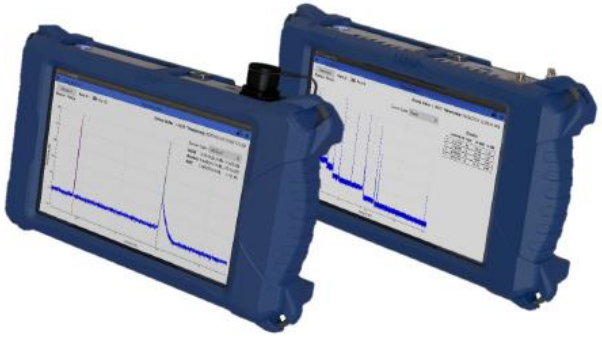
Summary / Q&A

- OBR: OTDR-like measurements
  - Ultra-high spatial resolution (<< 1 mm)
  - Ultra-high sensitivity

- *Website: www.lunainc.com*
- *Email: solutions@lunainc.com*
- *Sales Support: 1.866.586.2682*
- *Wajih's email: daabw@lunainc.com*



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