Brunno Huttner

Photon counting OTDR with dead zone 0,1 m -

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Issues Facing Fiber Assemblies and Networks

- **Installation**
  - Are the fibers installed correctly?
  - Are splices and connectors made correctly?
- **Commissioning**
  - What is the total loss budget?
  - What is the optical return loss?
- **Maintenance**
  - Where is a fiber break? Pinched fiber? Bad connector?

Similar issues, difference in scale (km vs. m)

→ **Need testing equipment: OTDR**

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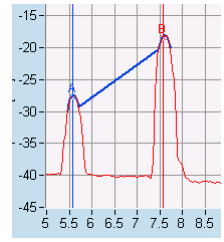
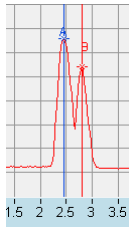
OTDR parameters: Resolution

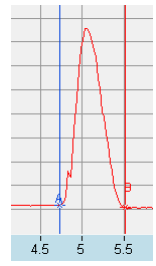
Three different concepts:



1. **Precision of length measurement**
   (also known as one-point resolution)



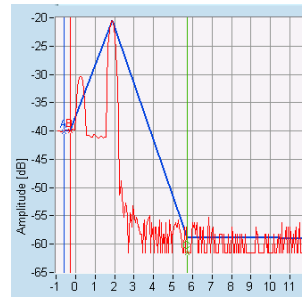
2. **Event deadzone (EDZ)**
   (also known as two-point resolution)
   Minimum distance needed in order to separate events



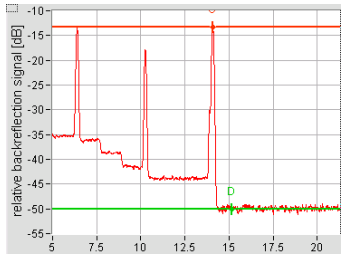
3. **Attenuation deadzone (ADZ)**
   Minimum distance needed in order to measure IL after a reflective event

OTDR parameters: Dynamic Range

Two different concepts:



1. **IL dynamic range**
   - "Usual" Dynamic Range
   - Distance between RBS and noise floor
   - ≈ Total loss acceptable in link
   - Often specified for longest optical pulses…
   - …But should also be specified for shorter pulses.



2. **RL dynamic range**
   - Maximum reflectance above noise floor
   - May be limiting factor for traces with high reflections and high resolution

Achieving high resolution: two demands

Higher resolution

↓

•Lower RBS signal

•Same reflection levels

Higher resolution requires:

More sensitive detection and higher RL dynamic range

Technology hurdle for High Resolution Reflectometry

High resolution

Weak RBS signal → High sensitivity

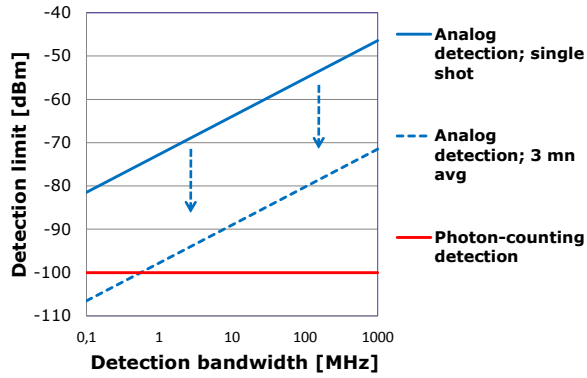
Short optical pulse → High speed detection

High sensitivity + High speed detection

Impossible with classical detection:

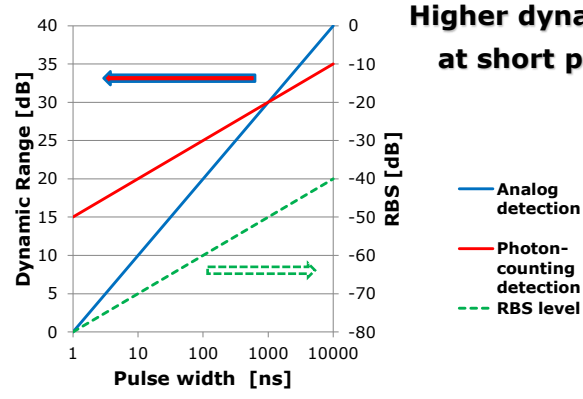
Need photon-counting detection!

Why Photon Counting detection?
High sensitivity with high speed



Photon counting detection has -100 dBm sensitivity and >1 GHz BW

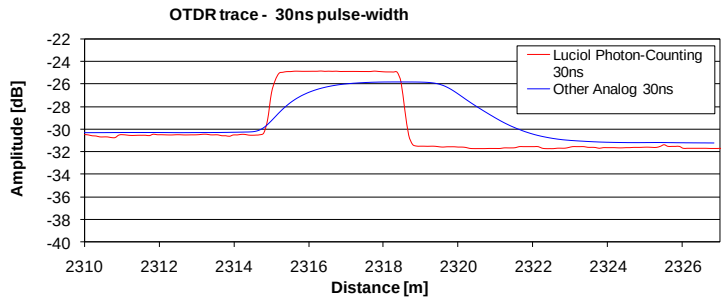
Why Photon Counting detection?
Higher dynamic range at short pulse width



Note: Assume input peak power of 10 dBm

Photon counting has superior DR for short pulses until 1 µs

Why Photon Counting detection?
Better resolution, even for long pulses



Same pulse width,
better resolution due to the large detection BW

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What type of instrument do you need?

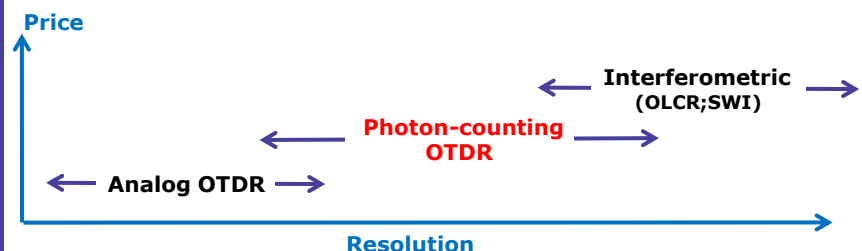
Distance range:

km | m | cm | mm

Application:

Optical Networks	PONs, FTTH	Fiber assemblies; Harnesses; Sensors	Components

Instrument:



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Scanning Photon-Counting OTDR

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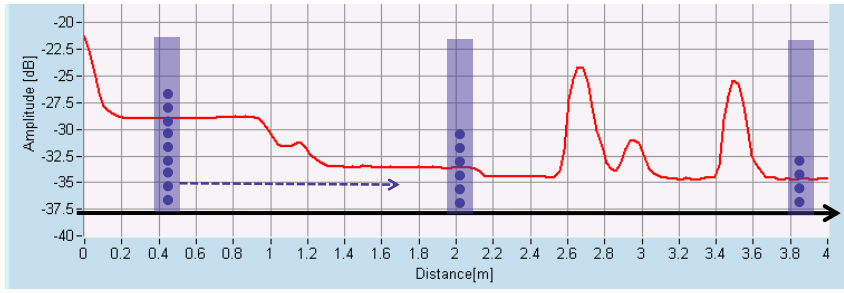
Principle of Scanning Photon-Counting OTDR

(US patent #7,593,098)



- **Generate short detection window**
- **Scan the detection window one step at a time**
- **Add variable attenuation at each step to get:**
  One pulse ➔ one count max.
- **Trace is a histogram with different # of counts**

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LOR-200 familly: Highlights

- **Fully portable instrument**
  - OTDR type of format
- **Can separate events with unprecedented resolution**
  - Shortest optical pulses in the industry: 1 ns ! matched with high-speed detection; Event deadzone as small as 10 cm
- **Can see any event, even after large reflections**
  - Attenuation deadzone: 40 cm (1 ns pulses, ORL= 45 dB)
- **Can see very weak reflections, even at short pulse lengths**
  - High sensitivity: can see signals down to -110 dB

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Some specifications: LOR-200

- Wavelengths : 1310 nm, 1550 nm, 1625 nm (for live mode PONs supervision)
- Optical power of the laser: ≈ up to +13 dBm output (peak power)
- User-selectable optical pulses lengths:
  2 ns – 5 ns – 10 ns – 30 ns – 100 ns – 300 ns - 1000 ns
- Maximum length of network: variable between 1.25 and 160 km
- Width of measurement window: variable, user-selectable
- Minimum spatial resolution (minimum distance between measurement points): ≈ 2.5 cm (0.25 ns)
- Event deadzone: 20 cm (2 ns pulses)
- Attenuation deadzone: 50 cm (2 ns pulses, ORL= 45 dB)
- DR : 18 dB for 2 ns pulses ;
  20 dB for 10 ns pulses.
- Number of measurement points: variable according to resolution
- Measurement time: ≈ 0.1 sec for each measurement point

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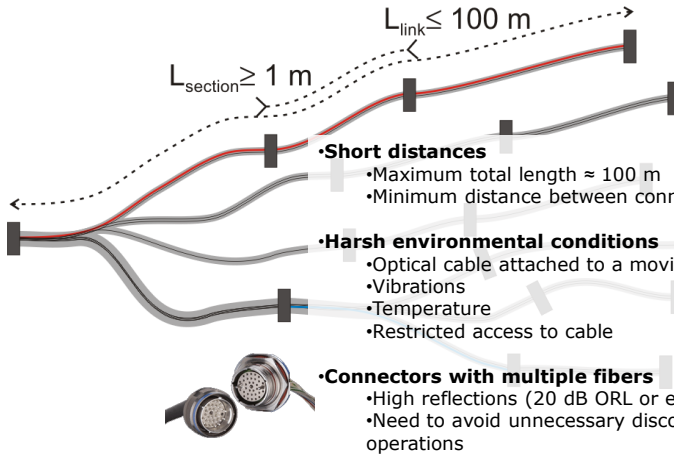
Some specifications: LOR-220

- Wavelengths : 650 nm, 850 nm
- Optical power of the laser: ≈several dBm output (peak power)
- Fixed optical pulses length : 1 ns
- Maximum length of network: variable (several kms)
- Width of measurement window: variable, user-selectable
- Minimum spatial resolution (minimum distance between measurement points): ≈ 2.5 cm (0.25 ns)
- Event deadzone: 10 cm
- Attenuation deadzone: 40 cm (ORL= 45 dB)
- DR : > 20 dB
- Number of measurement points: variable according to resolution
- Measurement time: ≈ 0.1 sec for each measurement point

Main applications

1. Tests of MMF assemblies (650/850 nm)
   - Aerospace and aviation
   - Military
2. Tests of SMF assemblies (Telecom wavelengths)
   - Backplane analysis and troubleshooting
   - Sensors and sensor assemblies
3. Installation/Maintenance/ Monitoring of PONs
4. Custom applications
   - SMF@650 nm
   - Large core MMF
   - POFs
   - …

MMF : Specific issues for aviation



- **Short distances**
  - Maximum total length ≈ 100 m
  - Minimum distance between connectors ≈ 1 m
- **Harsh environmental conditions**
  - Optical cable attached to a moving structure (stress)
  - Vibrations
  - Temperature
  - Restricted access to cable
- **Connectors with multiple fibers**
  - High reflections (20 dB ORL or even less…)
  - Need to avoid unnecessary disconnect/reconnect operations

Need:
- **High resolution OTDR**
- **Portable/Integrated system**
- **High Dynamic Range on ORL**

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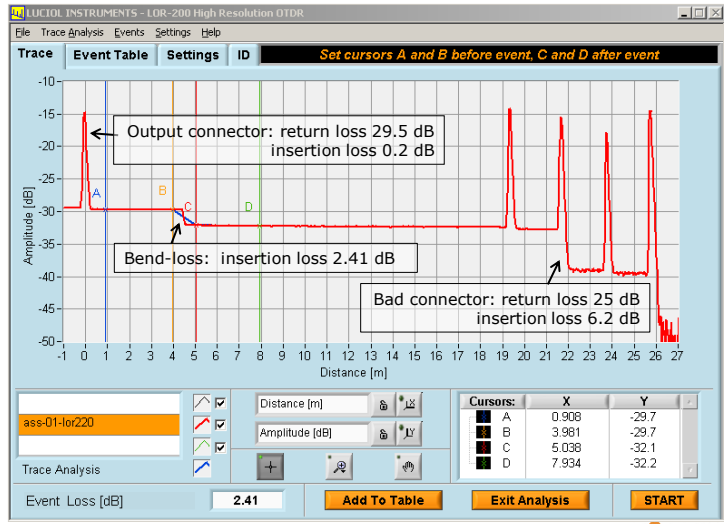
MMF : Easy characterization and troubleshooting: a fiber assembly with bend-loss and a bad connector



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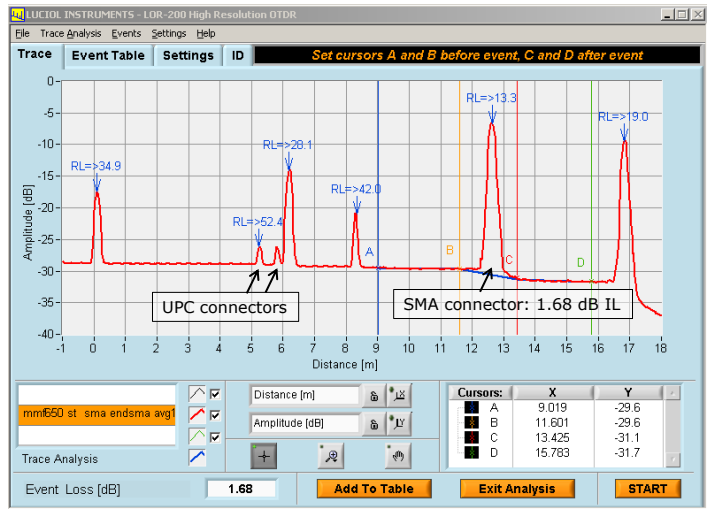
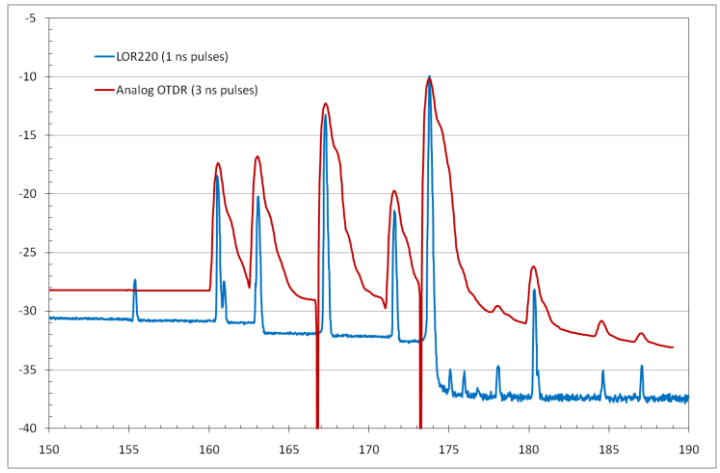
MMF: Measure IL and RL even for SMA connectors
Fiber assembly with UPC, PC and SMA connectors



MMF: Comparison between
an analog OTDR and a photon-counting OTDR
with large reflections, small reflections and IL



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SMF applications with LOR -200
A long SMF, with several connectors

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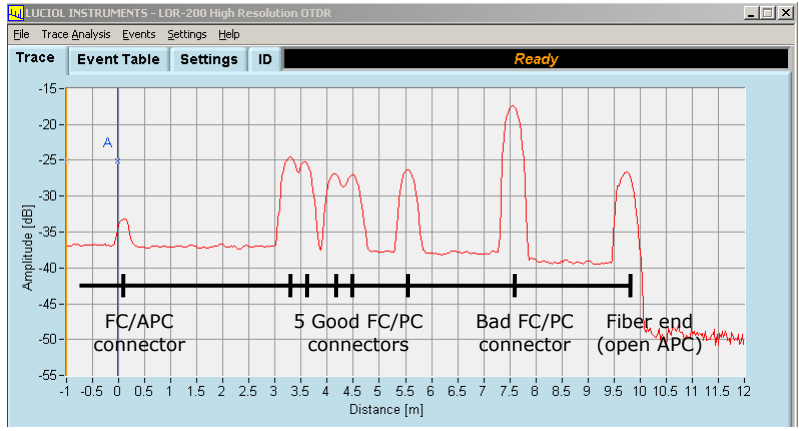
SMF applications
Analysis of a short SMF assembly at 1310 nm



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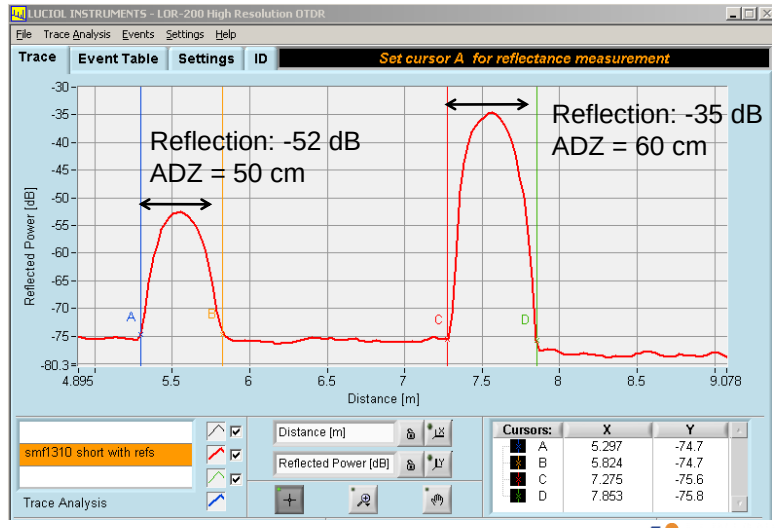
SMF applications

SMF@1310 nm: Attenuation DeadZone



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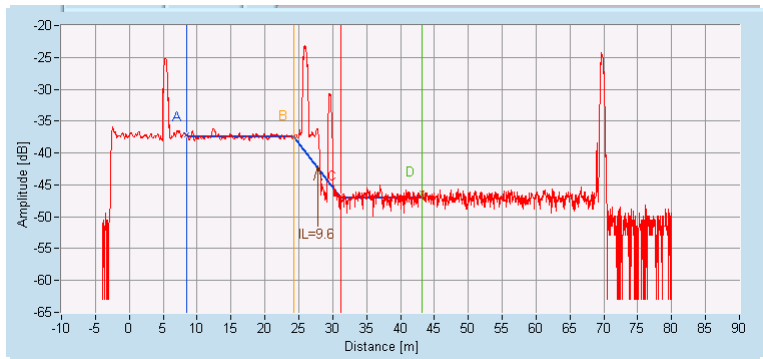
SMF applications

See 10 dB loss over a meter…



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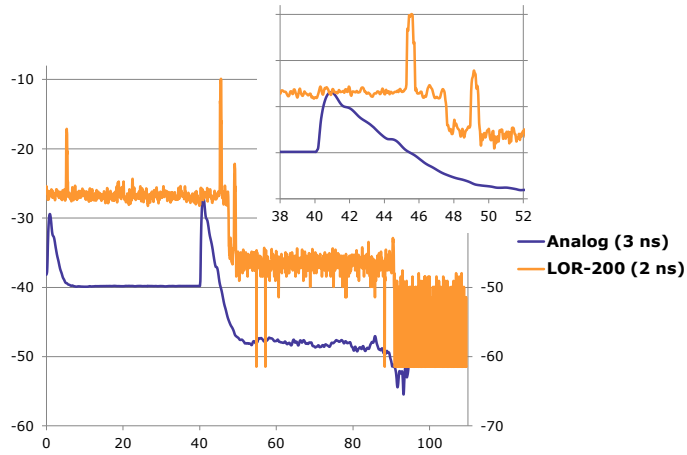
SMF applications
Comparison: Analog OTDR vs. LOR-200



Note: same setup, trace displaced for visibility

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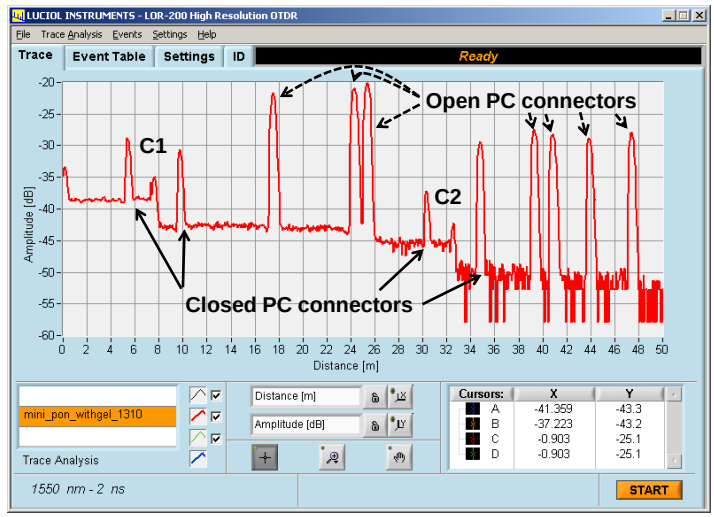
PONs applications :
mini-PON with 2 1X4 couplers



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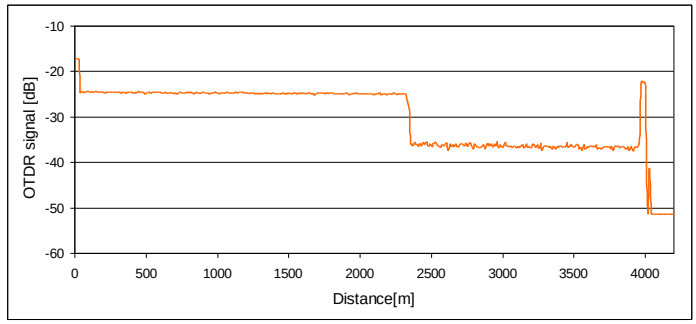
PONs applications :

PON with 2 1X8 couplers, length 3.9 km; pulses 300 ns



- ODTR trace taken from Central Office
  - Front panel reflection at 0 m
  - Coupler C1 at 2.3 km
  - Coupler C2 at 3.9 km
  - 8 ONT reflections immediately after C2 (non-separable on this scale)

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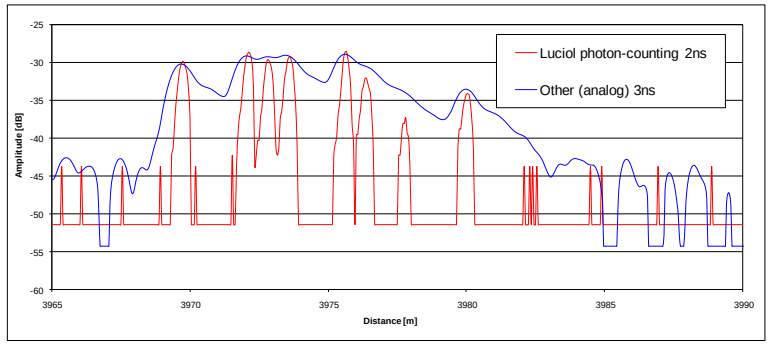
PONs applications : PON with 2 1X8 couplers zoom on ONT reflections after 3.9 km



- An analog OTDR with3 ns pulse width cannot resolve all reflective events (blue trace)
- The LOR-200 OTDR with 2 ns pulse width shows all 8 events and their correct reflectance (red trace)

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Summary

- High resolution system (typical: cm range)
- Measures IL and RL of multiple events, even on short leads (m range)
- Can have
  - either variable pulse widths (from 2 ns) for extended network characterization (LOR-200);
  - or highest resolution with 1 ns pulses (LOR-220).
- Accurate zooming on far-away events
- SMF system specially designed for PON (point-to-multipoint)
- MMF system specially designed for Aviation, Defence, Sensors…
- Available for most fiber types and wavelengths

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