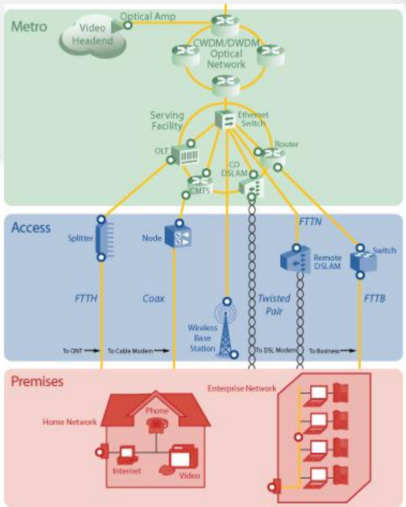
JDSU

You know us because you depend on our technology every day.



CommTech 2012

FTTH/Node/Curb –
Deploying and Supporting FTTx Architectures

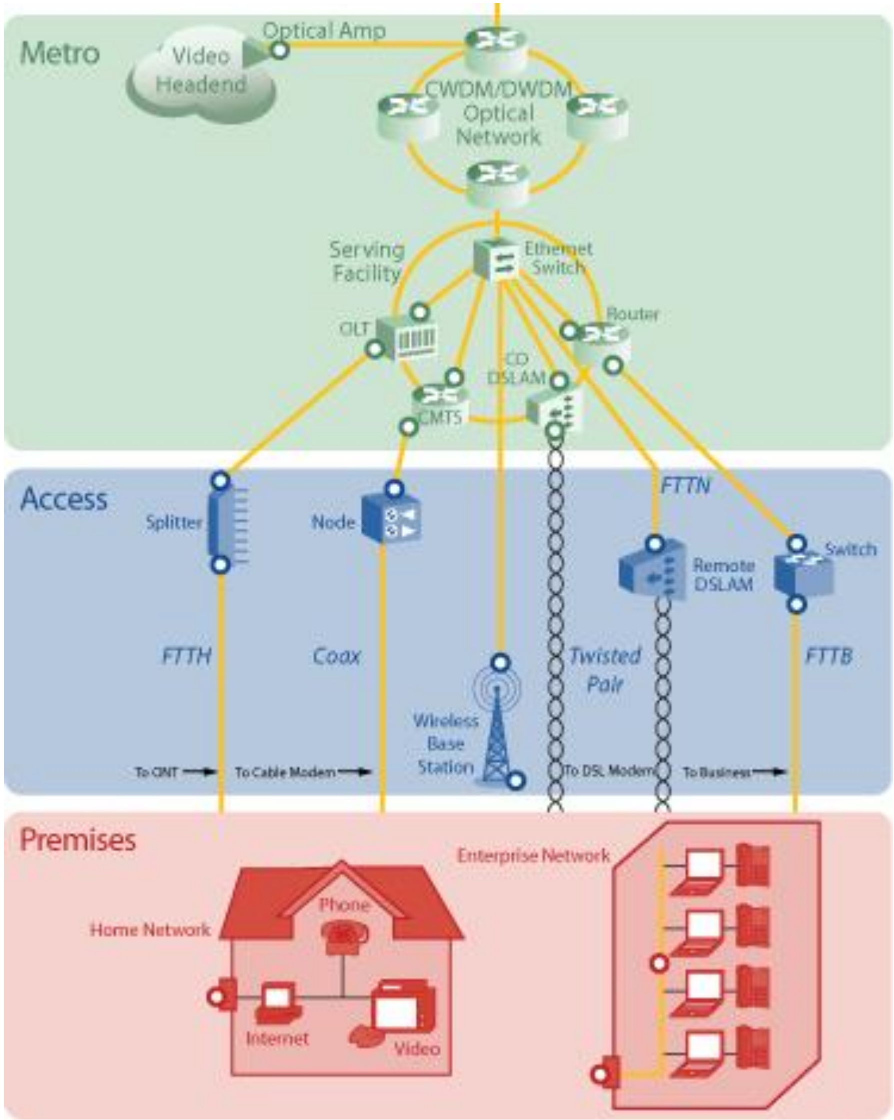
Tim Yount –
FO Test Solutions - Market Development
tim.yount@jdsu.com

Agenda

- Review of FTTx Topologies
- FTTH - Network qualification – ensuring a solid fiber infrastructure
- Connector Inspection
- Testing Fundamentals (Power, Loss, ORL, OTDR)
- FTTB – Splitters vs. xWDM – which is best?
- What’s next?

A quick review of FTTx topologies

- Fiber to the Home / MDU
  - PON, GPON, Splitter based
- Fiber to the Node
  - P2P to Node/ Coax to Premise
- Fiber to the (IP) DSLAM
  - P2P to DSLAM / TWP to Premise
- Fiber to the Business
  - P2P / DeMux cWDM (λ to biz)
- Fiber to the Antenna
  - Backhaul to x / Front haul x to / up tower or DAS



Past – Technology Discussions have centered around

- The need for PON Selective Power Meters to test down/upstream levels during turn-up
- Dealing w/ expertise needed for analyzing OTDR results
- Is there a need for 1490 nm OTDRs in FTTH?
- Can we troubleshoot through splitters? How?
- IEC standards on fiber inspection & why endface inspection practices are so important

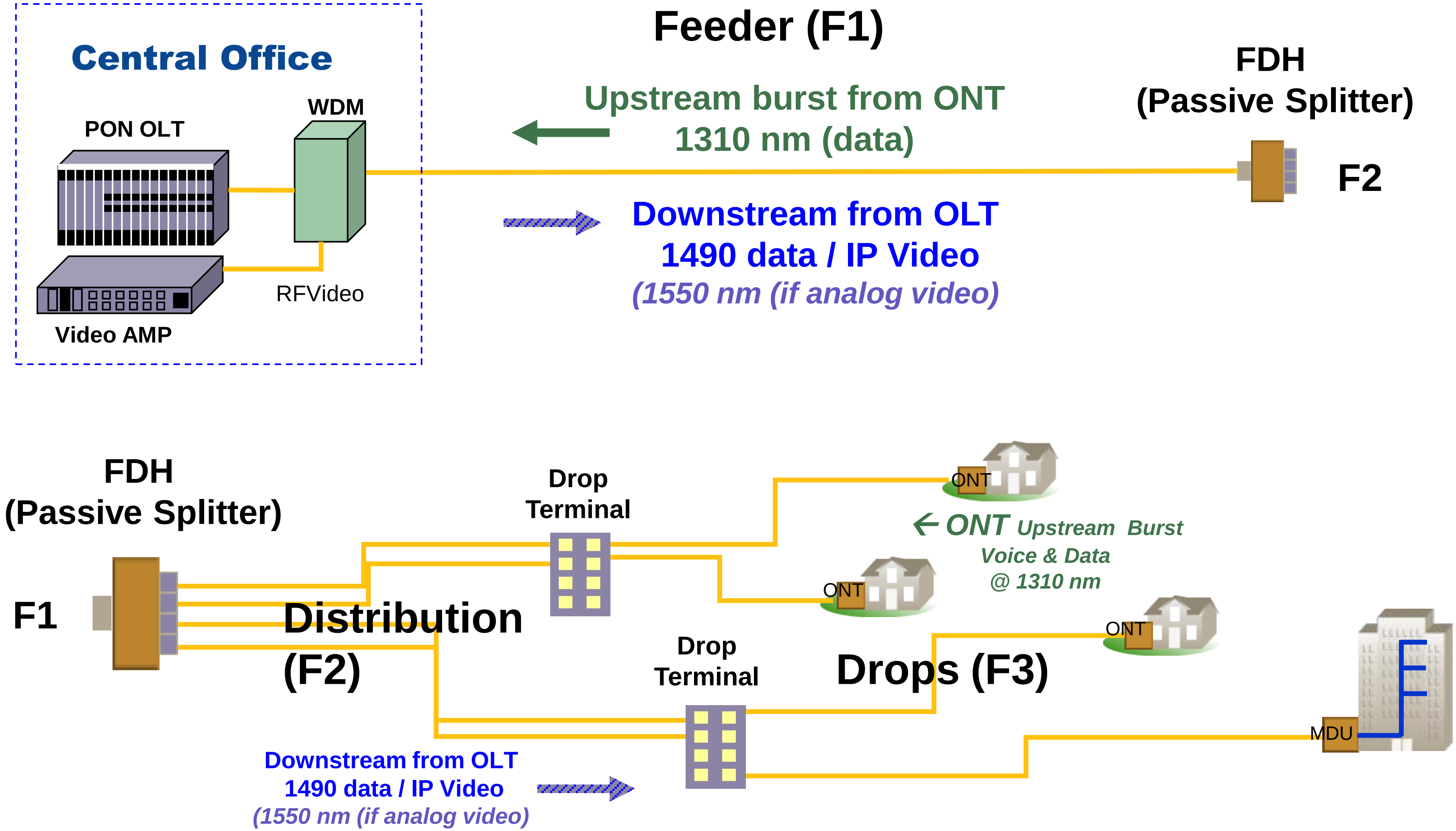
Today – More discussions/ dialogue around Workflow / Automation and Environment

- Dealing effectively w/ harsh environments
- Transitioning thinking/ approaches from copper to fiber world
- The challenge of simplifying / optimizing the testing phase
- Reducing the training required to ensure effective deployments
- The evolution of workflow-based test solutions
- Making connector inspection part of the integrated process
- How to ensure your fiber infrastructure will support future growth/ evolution
- PON monitoring is now a reality
- There is not a single best practice

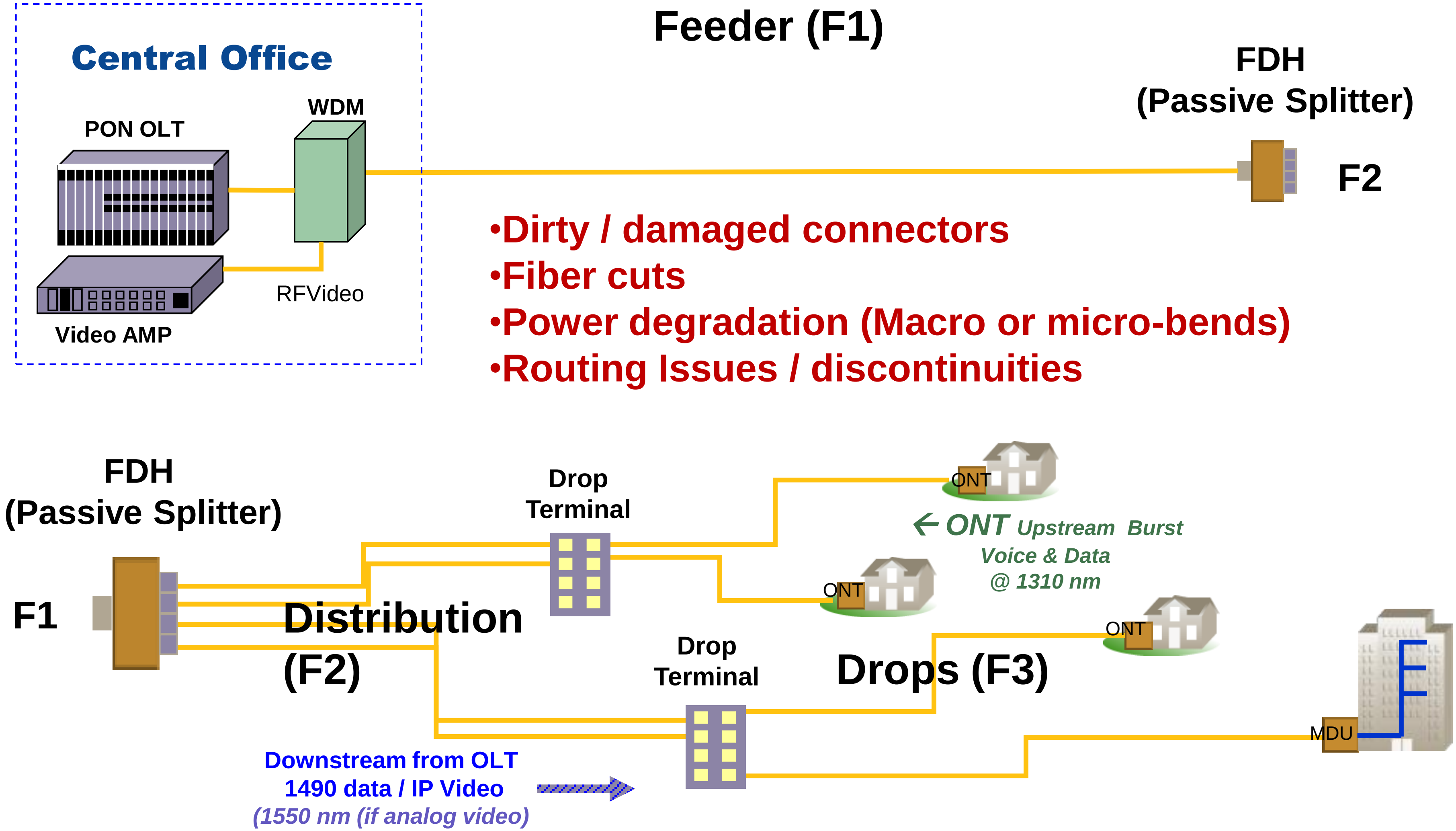
Traditional PON Standards

	B-PON	G-PON	E-PON
Max # Branches	32	64 (128)	32
Speed (Gbits/s)			
Downstream	155 .620 1.25	1.25 2.5	1.25
Upstream	.155 62	.155 .62 1.25 2.48	1.25
Wavelengths (nm)			
Downstream (Voice, Data)	1480-1500	1480-1500 *WDM overlay possible*	1490
Upstream	1260-1360	1260-1360	1300
Downstream (RF Video Overlay)	1550	1550	1570
Reference Standards	ITU-T G.983.x	ITU-T G.984.x	IEEE 802.3ah

FTTH Network Key Fiber Sections



Most common fiber problems you will encounter



FTTH Topology Details & Testing Overview

Basic stages of fiber tests

Construction & Acceptance: Conn Inspection, Insertion & Return Loss, OTDR

ONT install & Turnup: Inspection, PON Power Meter (VFL, I-S OTDR if TS needed)

Operational Troubleshooting: Inspection, OTDR

- If section isolated or out of service (1310/1550)
- OTDR In-service (1625 or 1650 filtered)

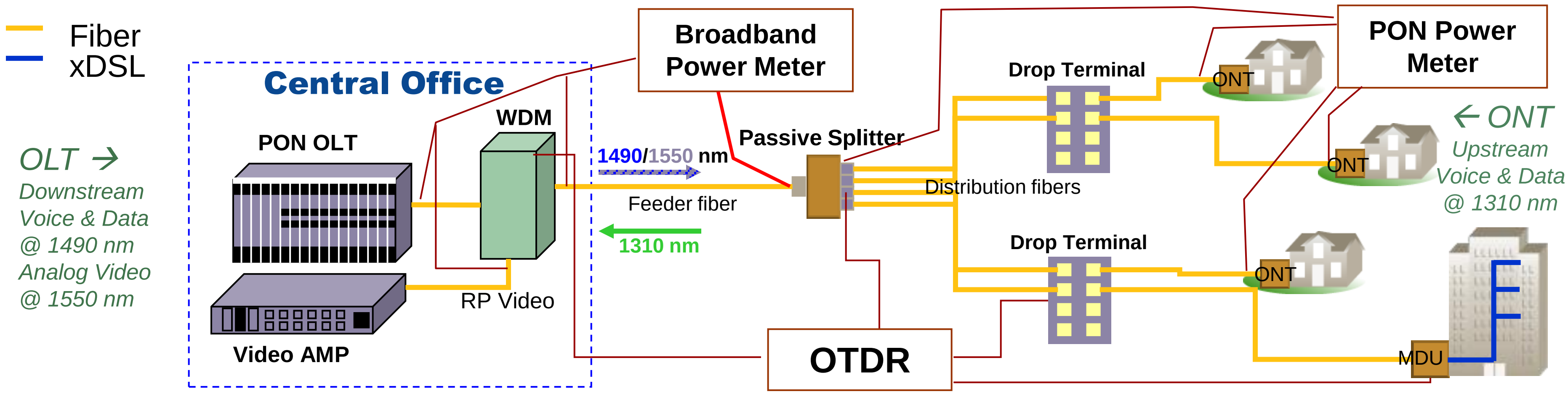
broadband@work TIP:

1490nm performance verification is addressed by testing @ 1550nm

Connectorized hub above/below splitter adds test flexibility (isolate from traffic)

Don't confuse PON selective power meter w/ Broadband power meter

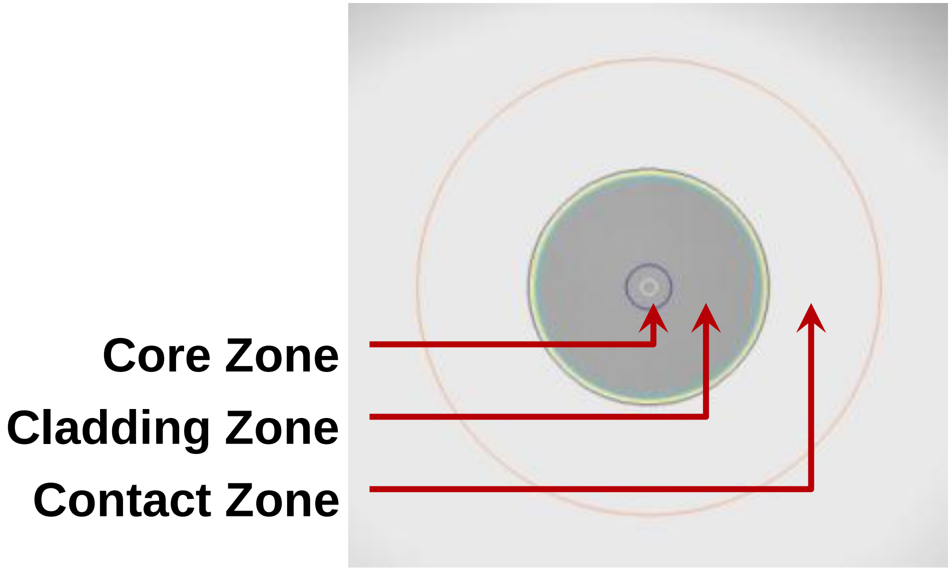
Proactive inspection/ cleaning speeds deployment / minimizes problems



IEC 61300-3-35 Acceptance Criteria

- These criteria are designed to guarantee a common level of performance
- Separate criteria for different connector types
  - SM-UPC (RL>45db)
  - SM-APC
  - SM-PC (RL>26dB)
  - MM
  - Multi-fiber

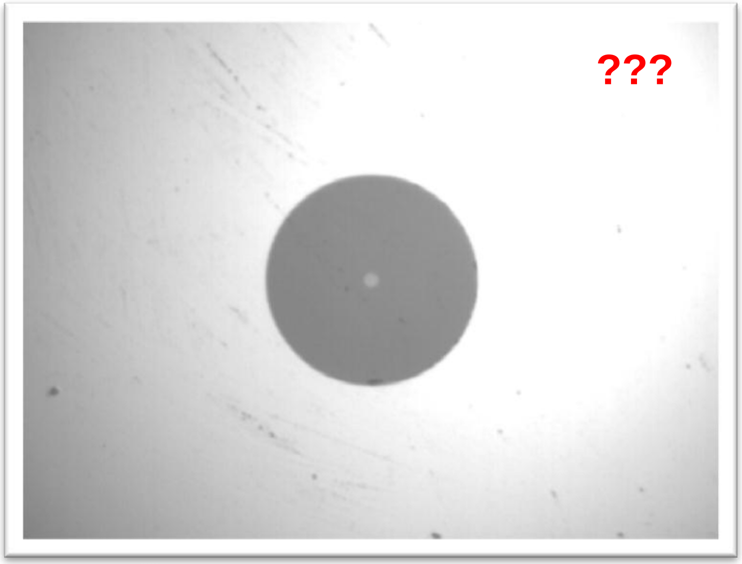
Example of Pass/Fail Criteria (SM-UPC)



ZONE NAME	SCRATCHES	DEFECTS
A. CORE (0–25µm)	None	None
B. CLADDING (25–120µm)	No limit <= 3µm None > 3µm	No limit < 2µm 5 from 2–5 µm None > 5µm
C. ADHESIVE (120–130µm)	No limit	No limit
D. CONTACT (130–250µm)	No limit	None => 10µm

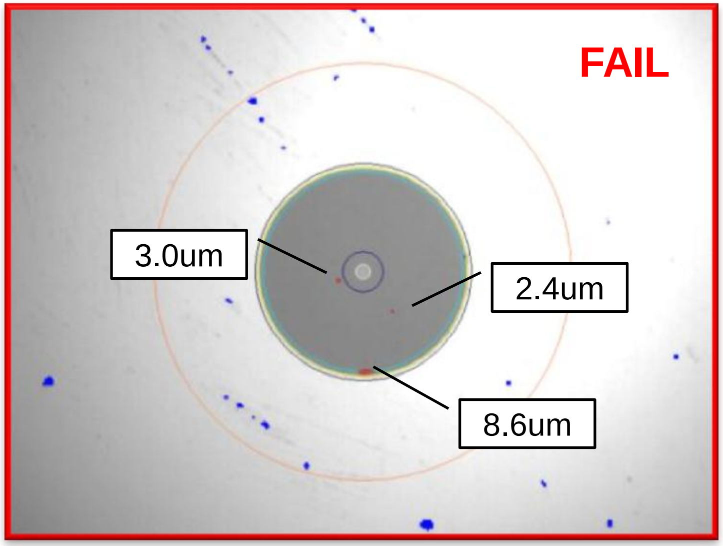
Does this connector PASS or FAIL?

SUBJECTIVE INSPECTION:



- Many Factors impact results:
  - Display settings
  - Ambient lighting
  - Operator eyesight
  - Operator judgment
- Actually testing is very difficult
- Certification is not practical

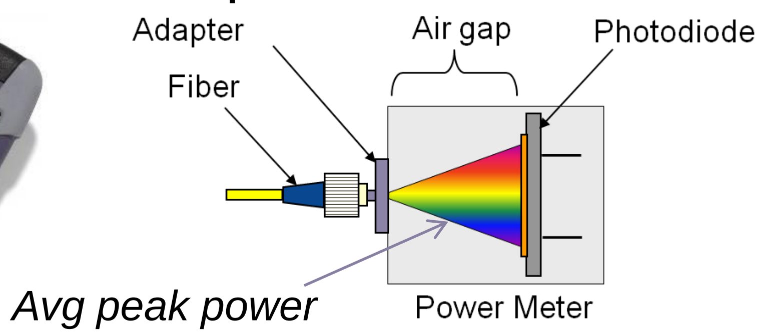
OBJECTIVE INSPECTION:



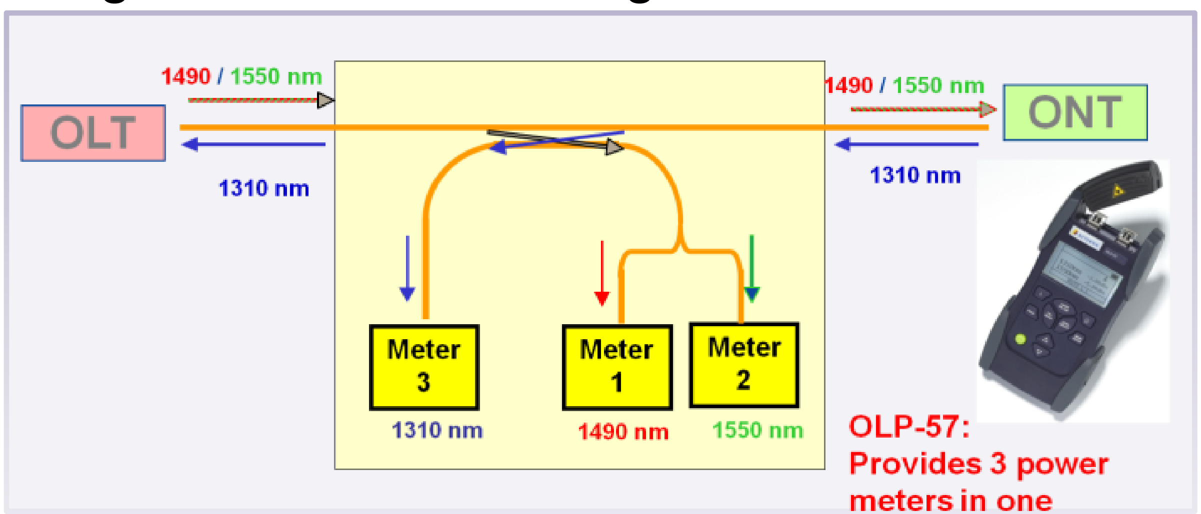
- Eliminate variation in results
- Certify and record product quality
- All skill levels can certify quality
- Make advanced criteria simple
- Improve performance & yields

Selecting the right meter for the right application

- Use a broadband power meter set to the correct wavelength to measure average power levels at various points in a network
  - @ transmitter
  - @ patch panel
  - @ receiver

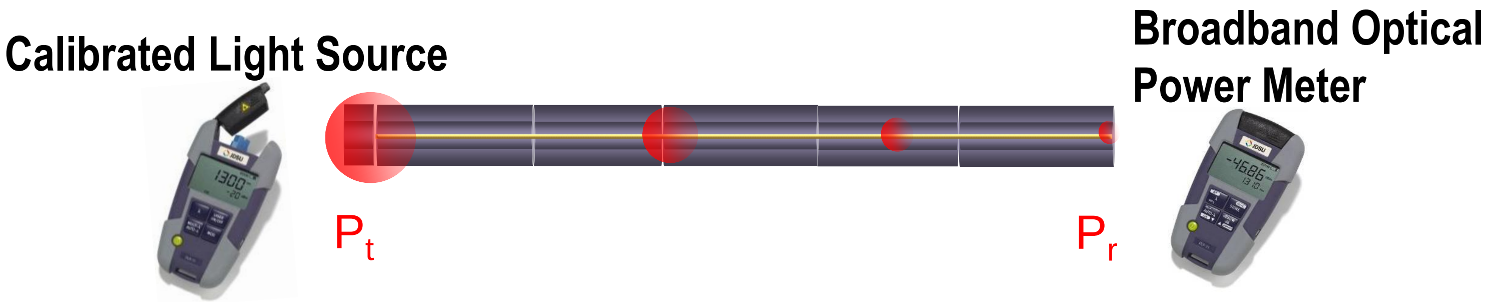


- Only in *PON (FTTH)* networks,
  wavelength selective “PON power meters” are used when measuring individual wavelengths channels within the fiber



Measuring Insertion Loss

- The insertion loss measurement over a complete link requires a calibrated source and a power meter.
- This is a unidirectional measurement, however can also be performed bi-directionally to optimize accuracy



It is the difference between the transmitted power and the received power at the each end of the link

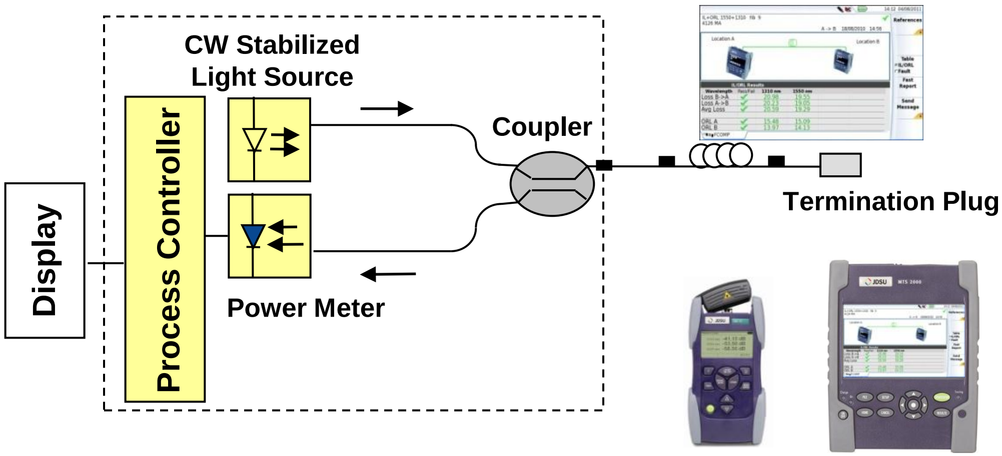
This measurement is the most important test to be performed, as each combination of transmitter/receiver has a power range limit.

Optical Return Loss (ORL) Measurement Methods

OPTIONAL TEST (see note)

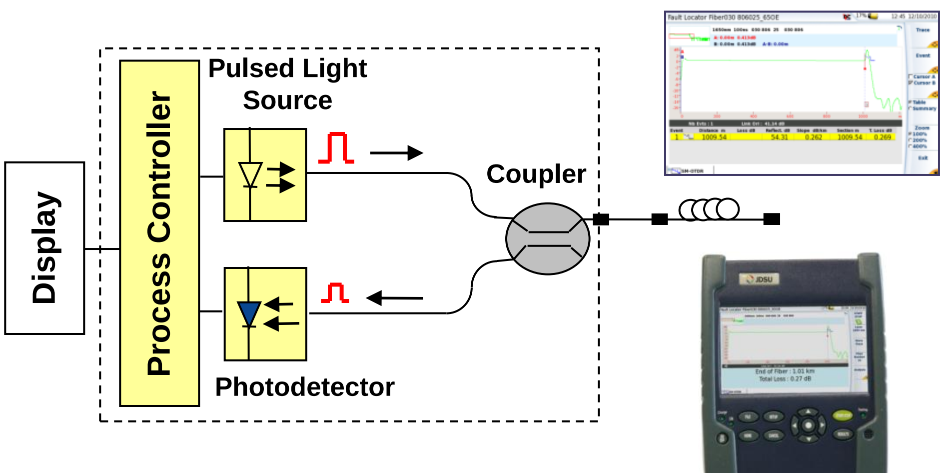
NOTE: ORL is generally required on all high power & high speed networks

Optical Continuous Wave Reflectometer



Accuracy (typ.)	**± 0.5dB**
Typical Application	**- Total link ORL & isolated event reflectance measurements during fiber installation & commissioning**
Strengths	**- Accuracy** **- Fast & real time info** **- Simple & easy results (direct value)**
Weaknesses	**- No localization**

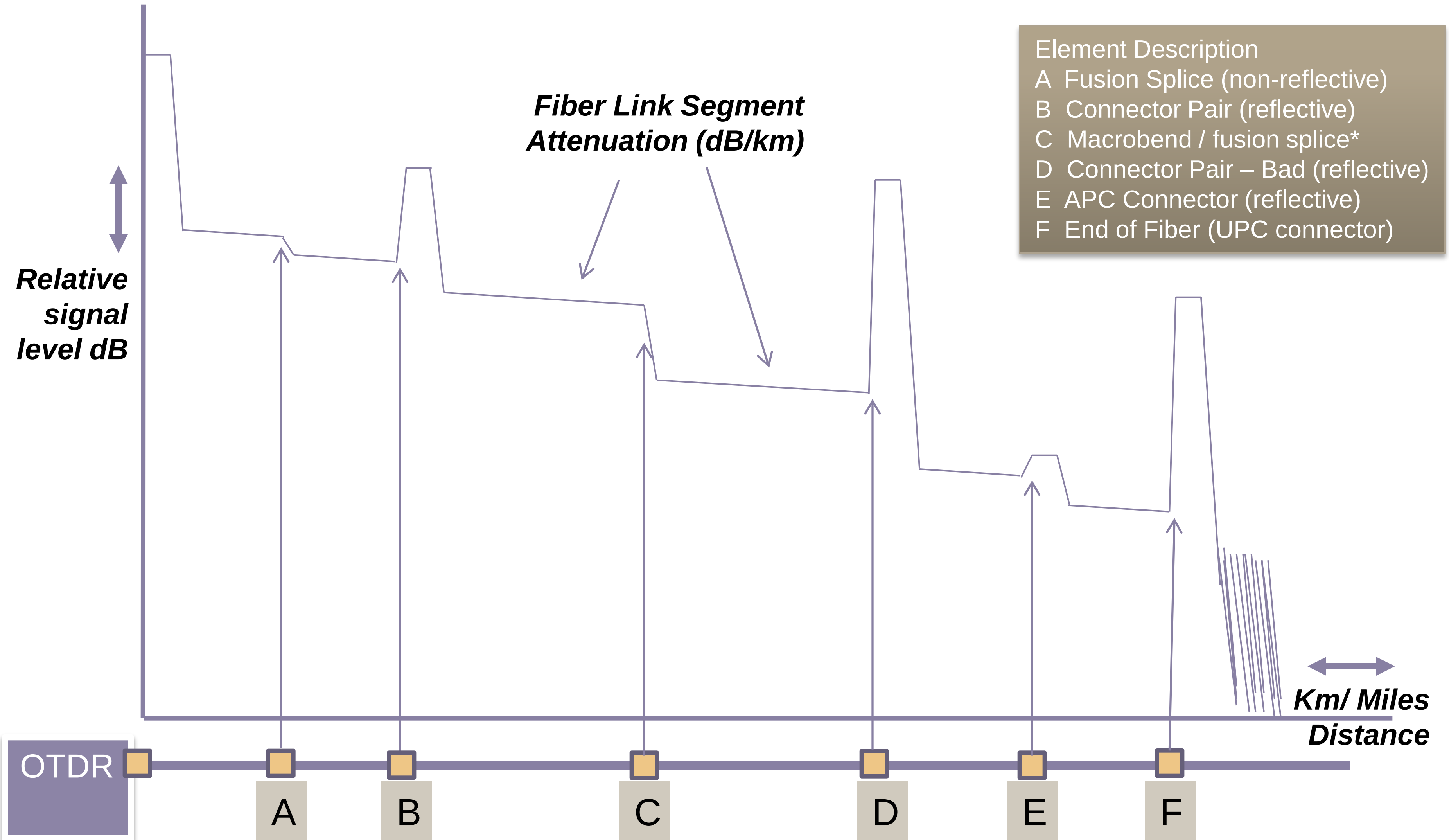
Optical Time Domain Reflectometer



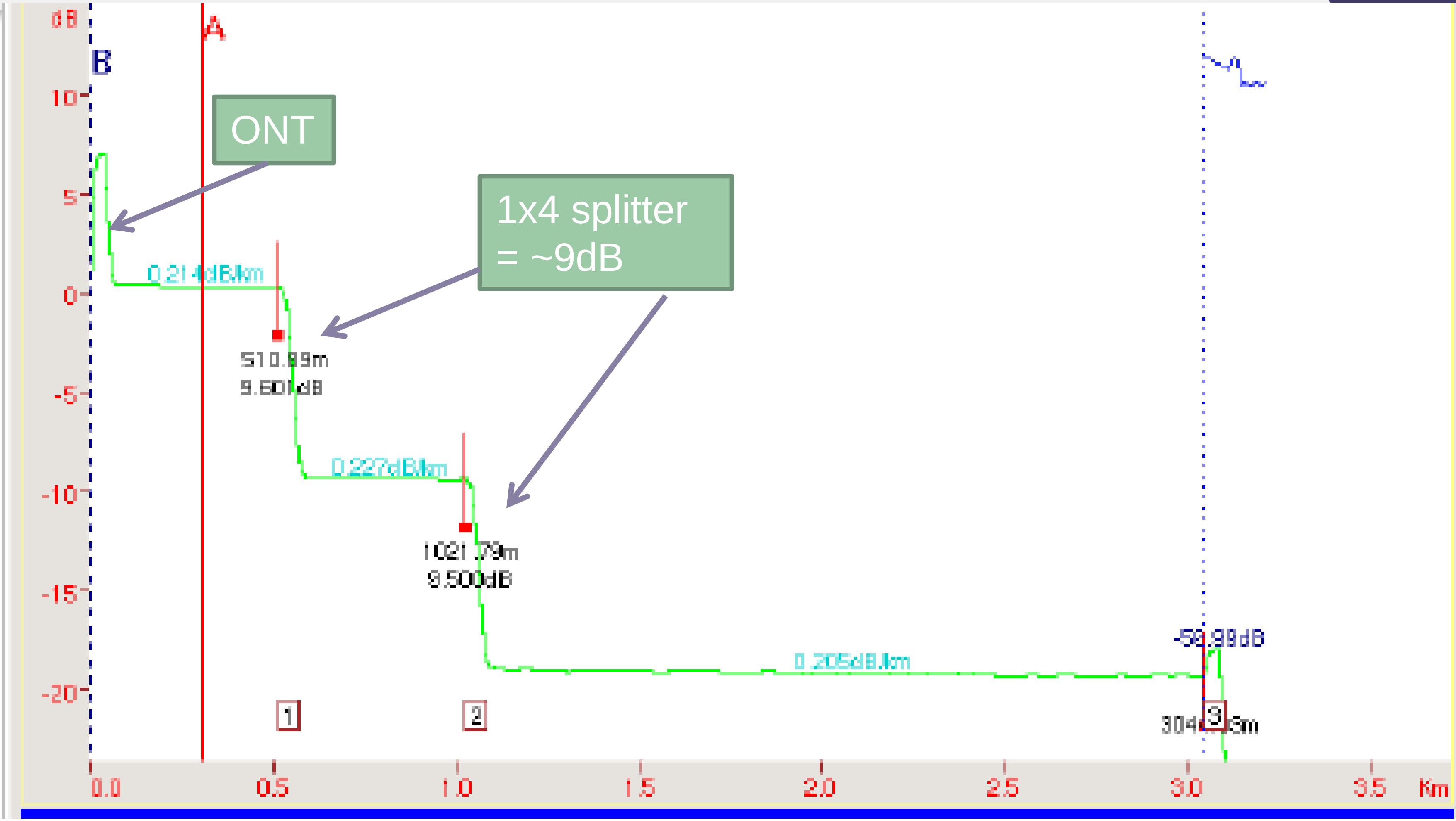
Accuracy (typ.)	**± 2dB**
Typical Application	**- Perfect tool for troubleshooting- Spatial characterization of reflective events & estimation of the partial & total ORL**
Strengths	**- Locate reflective events** **- Single-end measurement**
Weaknesses	**- Accuracy** **- Long acquisition time**

Optical Time Domain Reflectometer “OTDR” Display / Analysis

An OTDR sends light pulses down the fiber & collects the returned light from signal scattering & reflections. Many samples are processed to provide a usable trace.



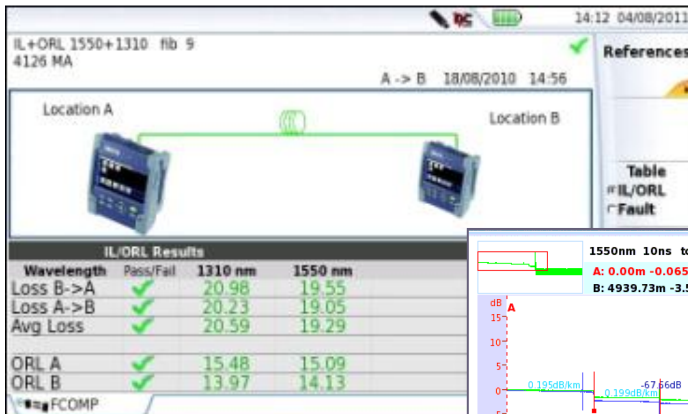
OTDR test from ONT through cascaded splitters



If troubleshooting w/o the entire splitter down, must be tested out of band (1625 or 1650 w/ filter)

Latest trend in fiber link Acceptance Testing

- One port integration and one-button automation of all key fiber link acceptance tests
  - *Insertion Loss (IL)*
  - *ORL (Return Loss)*
  - *OTDR*



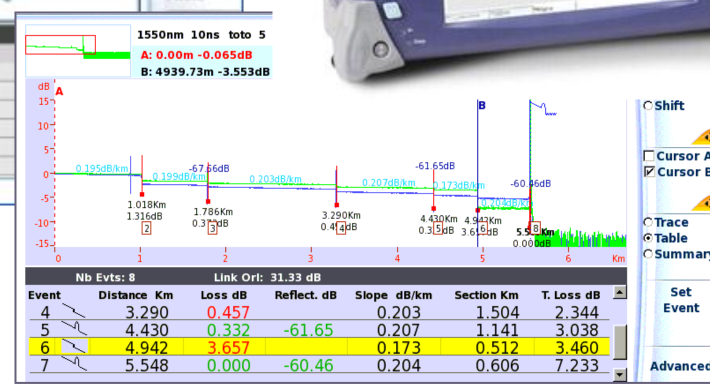
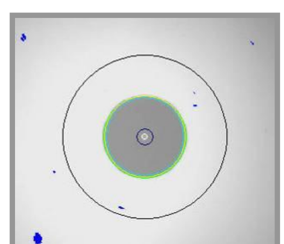


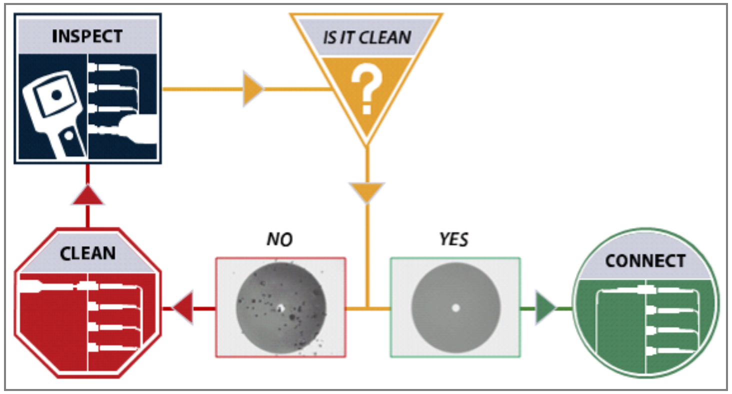
Table of Results display examples from T-BERD 2000/4000 FiberComplete



One button toggle: Inspection w/ Auto Pass/Fail

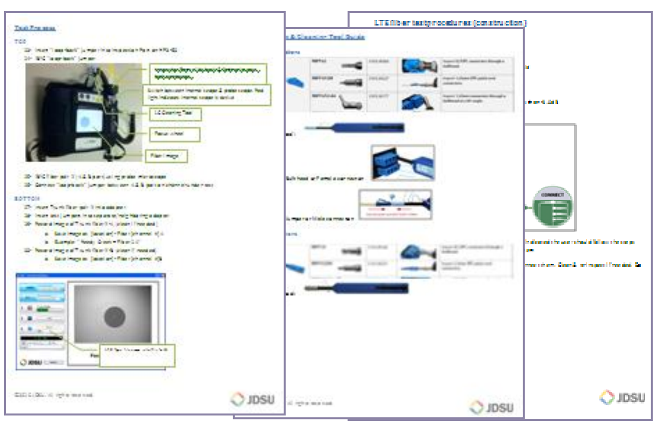
Fundamentals to optimizing FTTH fiber deployments

Establish best practices within your organization

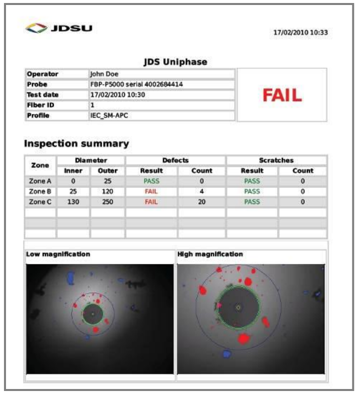


Drive industry standards

Ensure tech/installers follow proper procedures



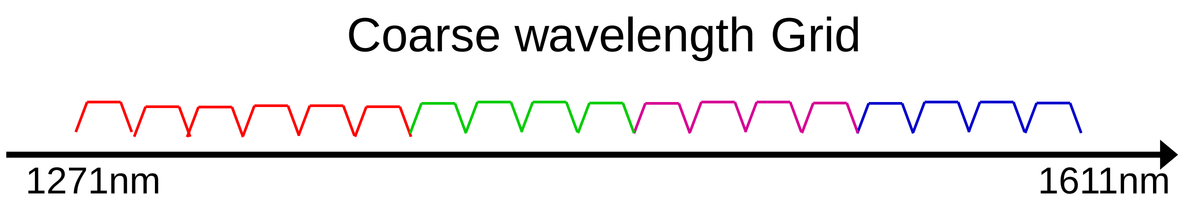
Confirm network compliance via certification reports



FTTB Fiber to the Business
Alternative to Splitter-based PON → CWDM

- Is split-based PON a good solution? Not for many business customers concerned w/ data security
  - In a 1:32 PON, all 32 premises receive all data – STB filters
  - For many businesses – several issues
    - Security – PON not secure enough
    - Not enough bandwidth

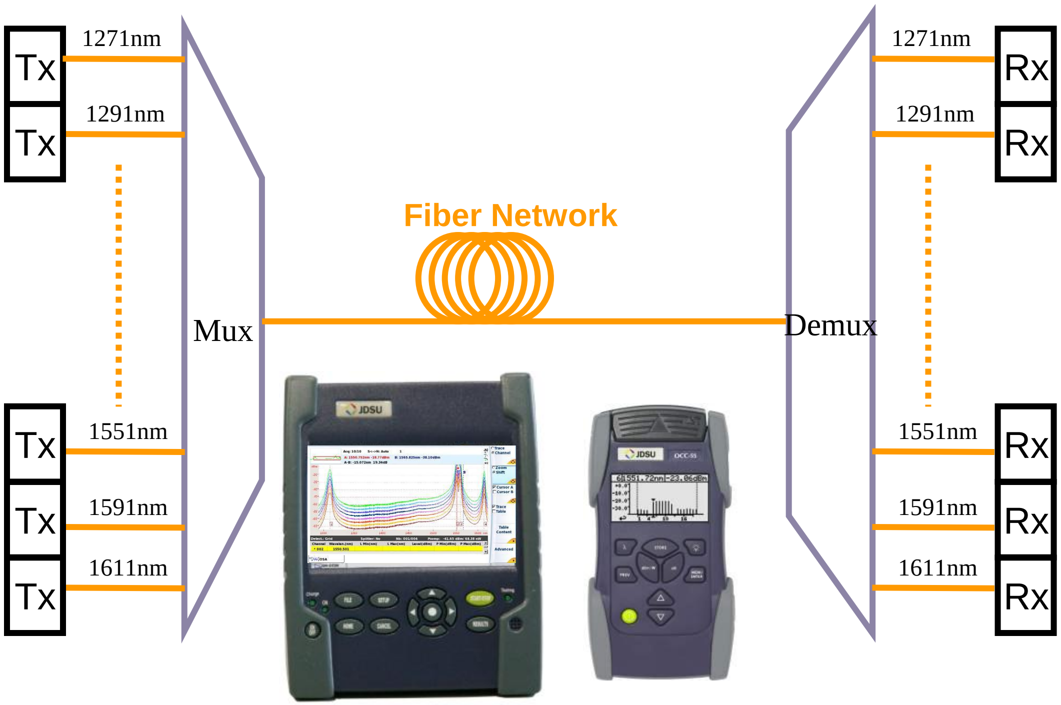
- One cost effective alternative – CWDM
  - Using a de-mux in place of the splitter separates the info for each customer on a different wavelength – better security / dedicated bandwidth



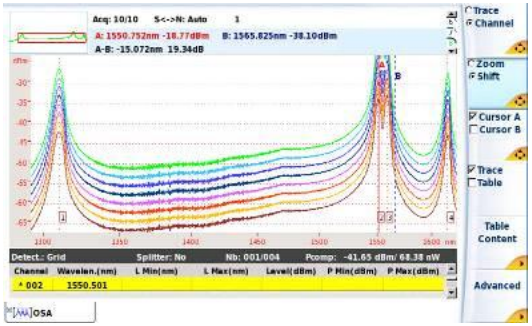
What is CWDM?

- Coarse Wavelength Division Multiplexing
  - Multiplexing a given number of channels: From 4 to 18 channels as per ITU-T G.694.2
  - In a limited environment: Distance range (<80km). No need for amplifiers, CD compensators…
  - Over a wide wavelength range (1261-1611nm)
    - new fibers available (All Wave …).
    - First step, use of 1471-1611nm
  - With a wide channel spacing (20nm)
    low cost components: Uncooled lasers, broad filters…

CWDM network testing



Dedicated λ(s) to each business



Unique tests recommended for CWDM (Turnup & Troubleshooting)

-CWDM OSA or Channel Checker (analyze channels – power, λ, drift)

-CWDM OTDR (trace of physical path each wavelength takes)

Next Generation PON Standards

	10 GPON	10 GEPON	RFoG RF over glass	*Pure* WDM-PON
Max # Branches	64 128/256 considered	64	64	64 128/256 considered
Speed (Gbits/s)				
Downstream	10	10	Like selected G/E-PON	May fall under NG-PON2
Upstream	NG-PON1/ XG-PON1: 2.5 NG-PON1/ XG-PON2: 10 NG-PON2: 10	10	Like selected G/E-PON	May fall under NG-PON2
Wavelengths (nm)				
Downstream (Voice, Data)	1480-1500 WDM overlay possible	1480-1500	1490	TBD
Upstream	1260-1360	1260-1360	1310 RF Return Path: 1570 or 1610	
Downstream (RF Video Overlay)	1550 or 1577nm	1577nm	1550nm	Yes, TBD
Reference Standards	ITU-T G.984.x	IEEE 802.3av	SCTE SP910	Not yet defined

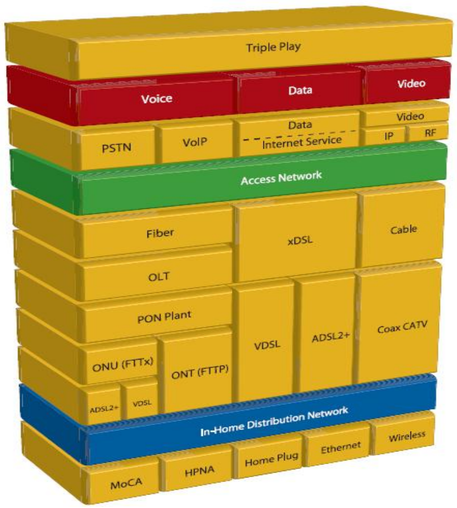
Key Points Summary

JDSU

80% of network problems due to dirty/damaged connectors

Correct testing of the FTTH fiber network is *critical to ensuring optimum performance.*

- Basic tests : Inspection, OTDR, IL, ORL, VFL
- Access PON networks require special inline selective power meters to check all down/ upstream wavelengths below splitter
- New solutions optimizing workflow and simplification of testing are available today



FTTx is still evolving

And REMEMBER…

ALWAYS *INSPECT BEFORE YOU CONNECT !*

Supporting Information

Standards & Influencing Organizations

FSAN
Full Service Access Network

ITU International Telecommunication Union

TIA

IEEE

Broadband.org Forums

IEC

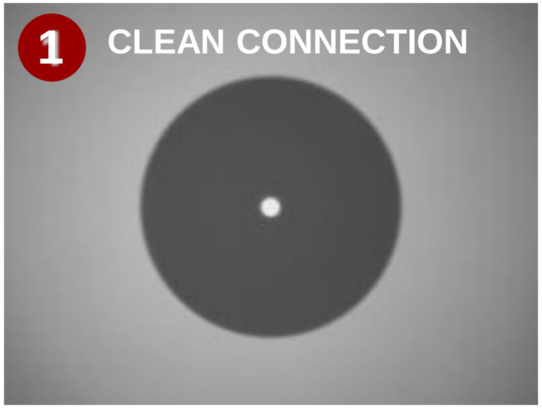
FTTH Council Europe

FTTH council fiber to the home

FTTH Council Asia Pacific

Contamination and Signal Performance;

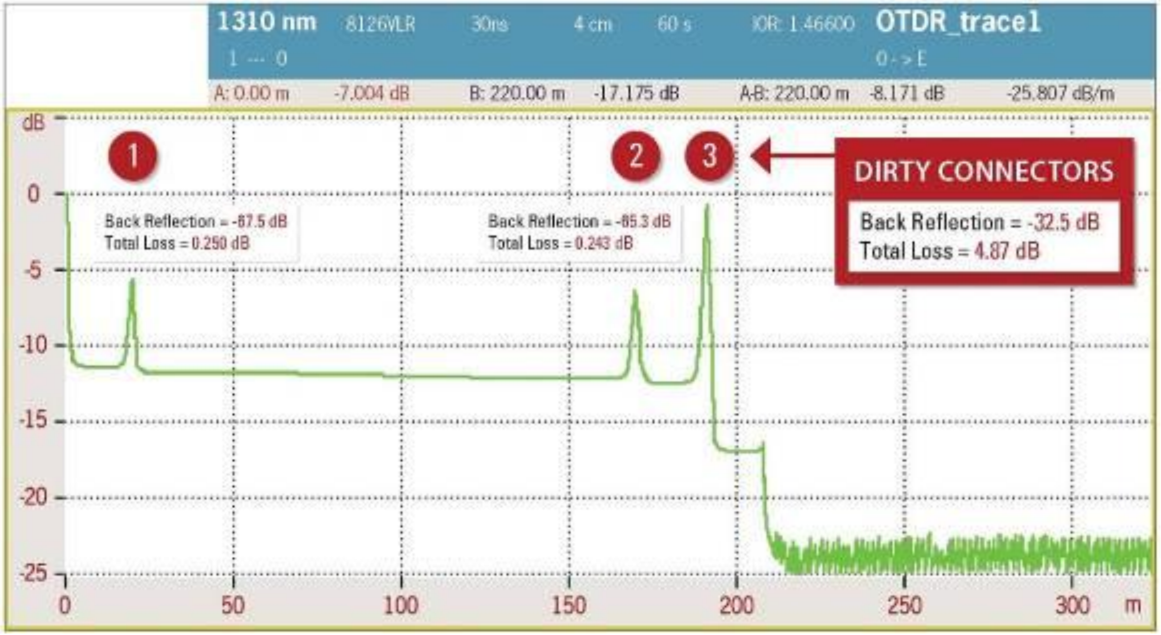
JDSU



Back Reflection = **-67.5 dB**
Total Loss = **0.250 dB**

Back Reflection = **-32.5 dB**
Total Loss = **4.87 dB**

Fiber Contamination and Its Effect on Signal Performance



Clean Connection vs. Dirty Connection

This OTDR trace illustrates a significant decrease in signal performance when dirty connectors are mated.

Example: All-in-one FTTx Network Tester

Applications

Network qualification testing & troubleshooting
- Fiber infrastructure – PON & CWDM
- Copper infrastructure

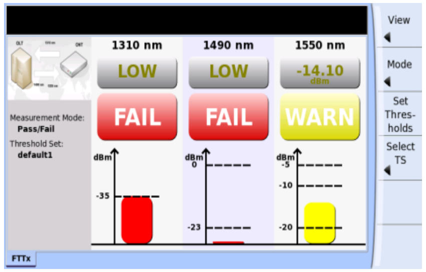
Service Turn-up & Troubleshooting
- POTS
- x-DSL
- VOIP
- IP-Video

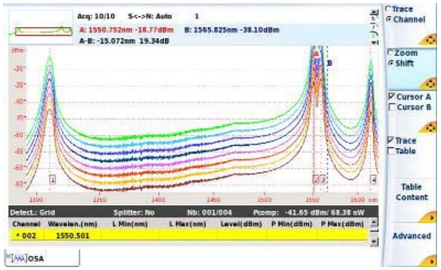
Testing Functions

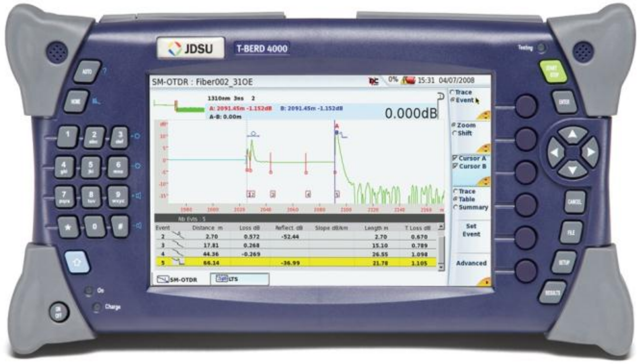
OTDR (includes thru-splitter testing)
PON Power Meter
Loss , ORL
CWDM OSA
Connector Inspection

FiberComplete

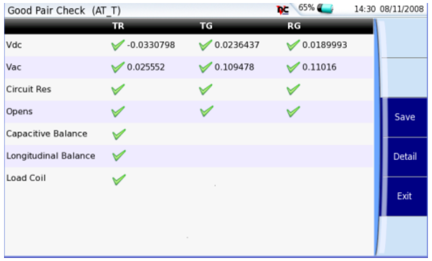
Copper TDR, Butt Set,
Set-top box emulation
Triple-Play Service turnup







T-BERD 4000



Basic Tests – Perform on all / most fiber links

- **Connector Inspection**

- **Optical Power**

- **Link Insertion Loss**

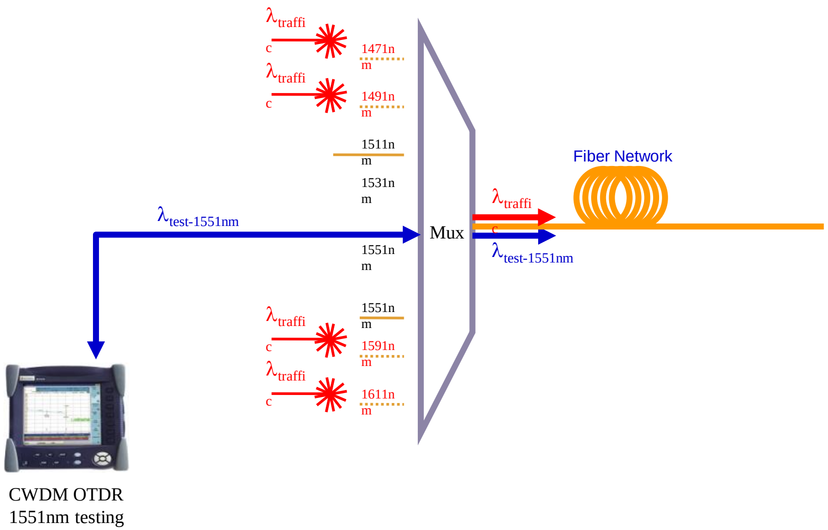
- **Link ORL**
  (not required on all networks)
- **Visual Fault Locator (VFL)**
  (as needed)

- **Fiber Identifier**

- **OTDR**
  - Distance
  - Loss (changes in backscatter levels)
    - Fiber sections
    - Link sections
    - Fusion Splices
    - Connectors
    - Macro-bends / Micro-bends
  - ORL
    - Link sections
    - Reflective events (reflectance)

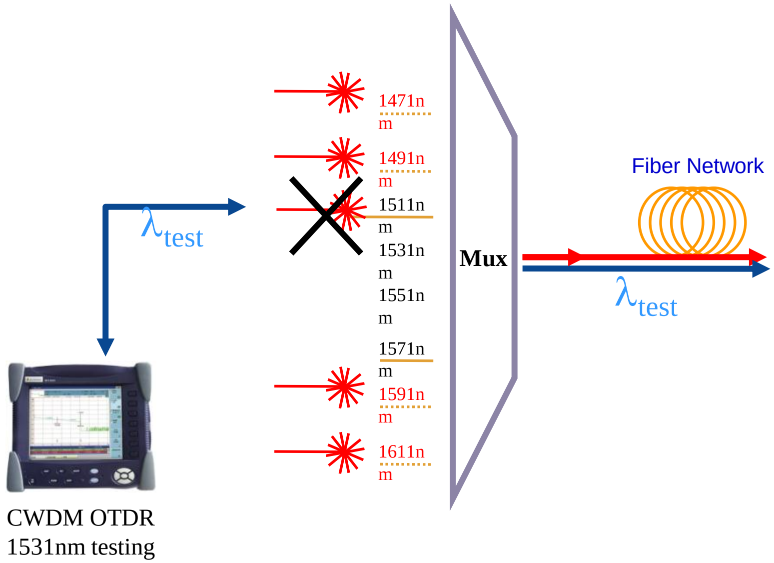
CWDM Wavelength Provisioning

- Test new wavelength route not yet in use
- make sure wavelength goes through
- In-service test when other wavelengths already active
  - OTDR test without disturbing current traffic
  - Reliable OTDR test taking other wavelength powers into account



CWDM Wavelength troubleshooting

- Shooting the defective wavelength without turning others off
  - In-service testing
  - No traffic deactivation
- Pinpoint any fault in the network according to the wavelength involved
  - Very short dead zone
  - Suitable dynamic range



WDM PON Standardization: NG-PON2

Standardization - FSAN

- Much effort on NG-PON is currently being done in pre-standardization and standardization bodies
  - FSAN/ITU-T for 10GPON and IEEE P802.3av task force for 10G EPON.
- **NG-PON1** is required to work over existing ODN's
  - **XG-PON1**: 10G downstream (DS) and 2.5G upstream (US) – this is the current focus of the FSAN operators – framing is "G-PON like"
  - **XG-PON2**: 10G symmetrical – longer term
- **NG-PON2** may require new ODN – loose requirements
  - Typically considering introducing WDM splitter (arrayed waveguide grating, AWG) at the RN
  - WDM-PON is the "hottest" candidate

In Progress

- XG-PON1 (G.987) is planned to be consented in ITU-T starting 2009
  - Physical layer (PMD) October 2009
  - Transmission convergence (TC) and Management (OMCI) in June 2010.

Done

- It is unclear when and exactly how WDM-PON will be standardized, possibly 1-2 years after XG-PON

In Progress

 Public 5 2009-10-05

Source: Ericsson 2010

Colorless Light Sources

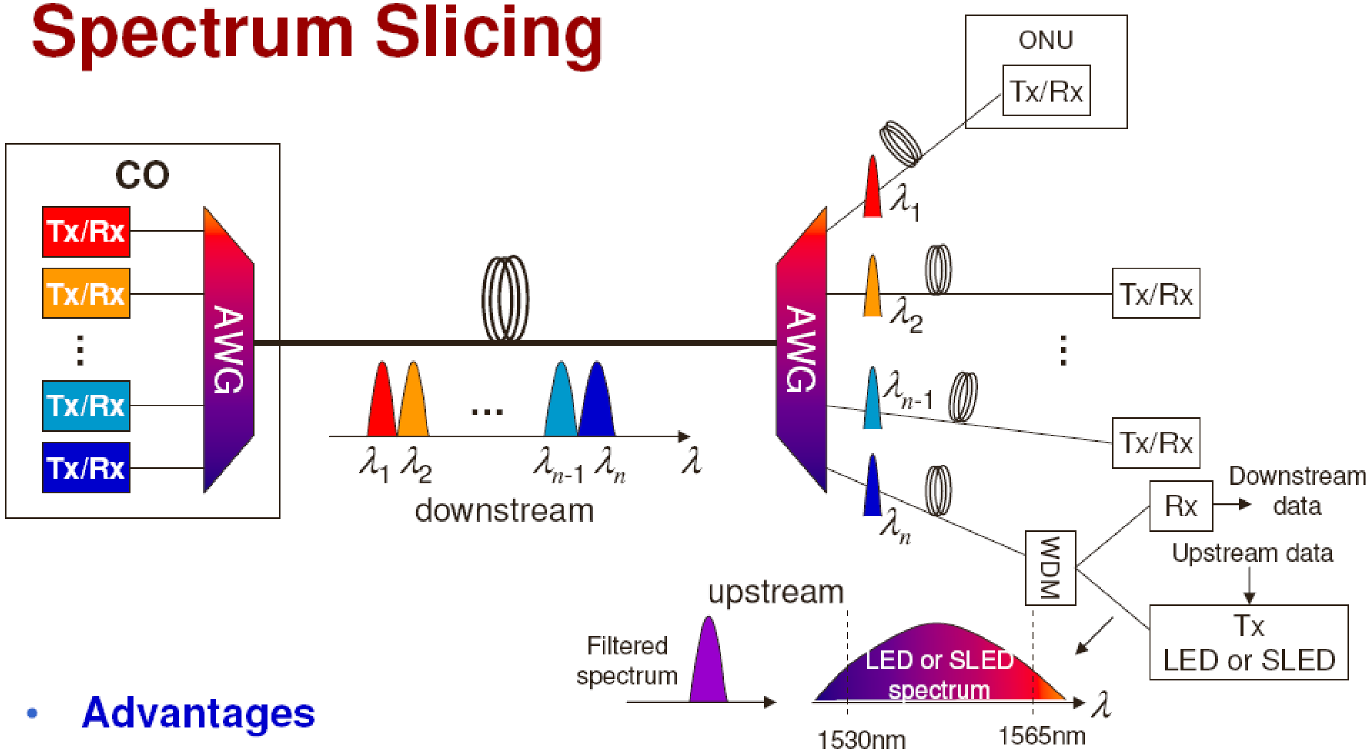
- **Spectrum Sliced Broadband Lightsource**
  - LED/SLED/SOA as colorless lightsource
  - Spectrum sliced by AWG for appropriate channels
- **Injection locked FP laser**
  - Specially designed FP laser as colorless lightsource
  - FP laser operates on the wavelength of external injected lightwave
- **Reflective Semiconductor Optical Amplifier**
  - Semincoductor optical amplifier as lightsource
  - External injected lightwave is amplified, modulated and reflected to CO
  - Using the saturation property of SOA, the downstream wavelength can be used as an injection to SOA and hence reused for upstream transmission
- **Tunable Laser**
  - Widely tunable semiconductor laser as colorless lightsource
  - Need protocol to set the operating wavelength

HUAWEI TECHNOLOGIES CO., LTD. Page 8 HUAWEI

Source: Huawei 2010

WDM PON Solution 1: Spectrum Slicing

Spectrum Slicing



- **Advantages**

  Low cost; no seed light is needed.
- **Disadvantages**

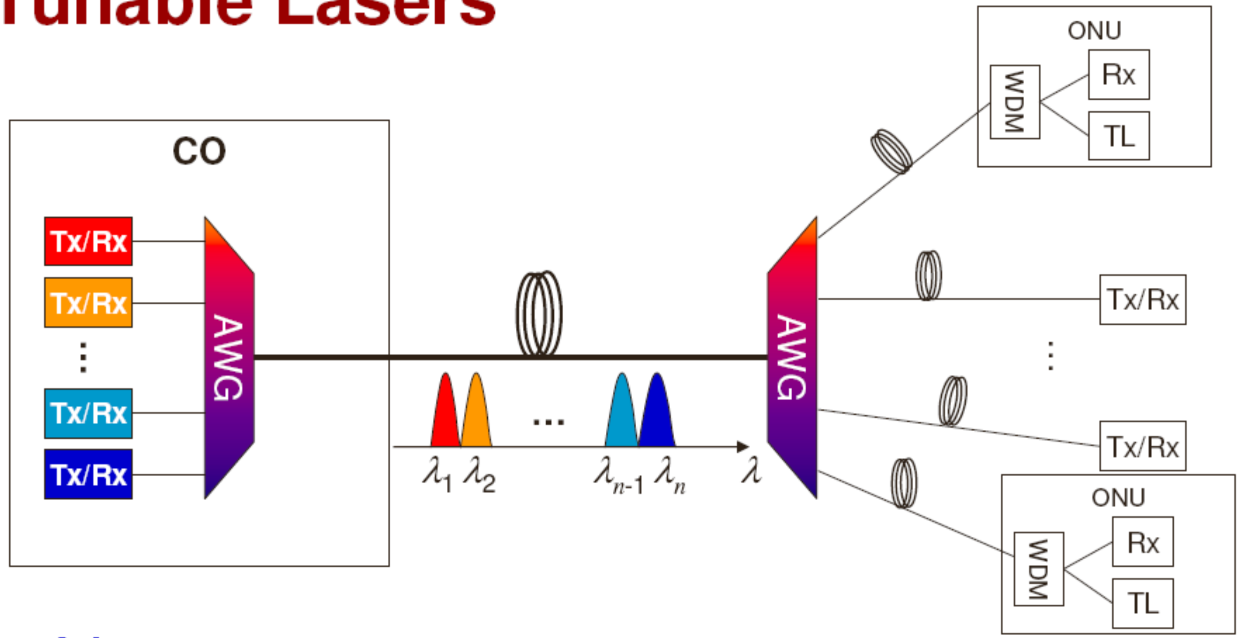
  Low bit rate (<155Mb/s), short transmission distance.

  Because of the low bit rate, spectrum slicing is not a good option for WDM PON

HUAWEI TECHNOLOGIES CO., LTD. Page 9 HUAWEI

Source: Huawei 2010

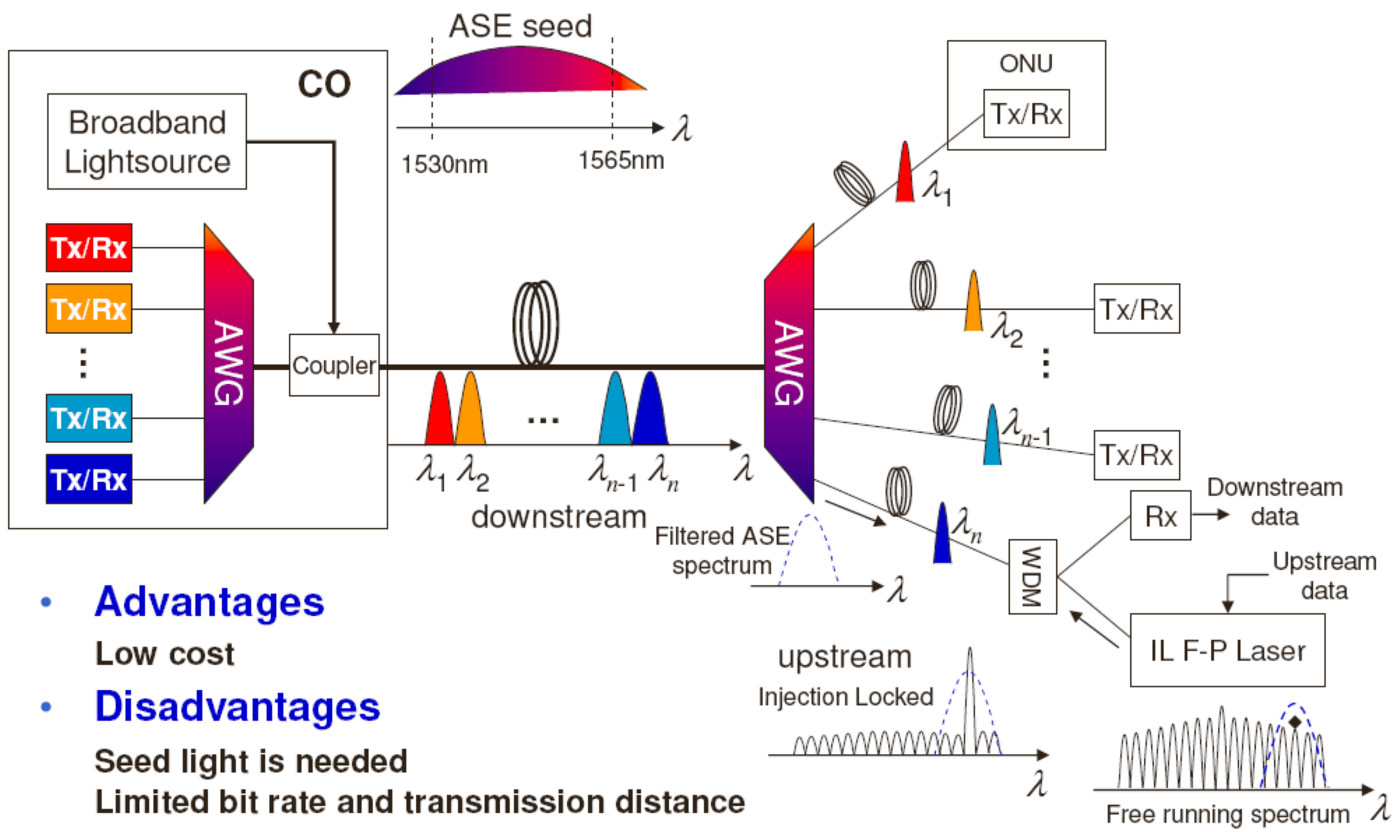
Tunable Lasers



- **Advantages**
  No Seed light is needed
  High bit rate(>2.5Gb/s), long transmission distance (~80km)
- **Disadvantages**
  Very expensive; dynamic wavelength assignment algorithm is needed

Source: Huawei 2010

Injection Locked FP Laser



- **Advantages**

  Low cost

- **Disadvantages**

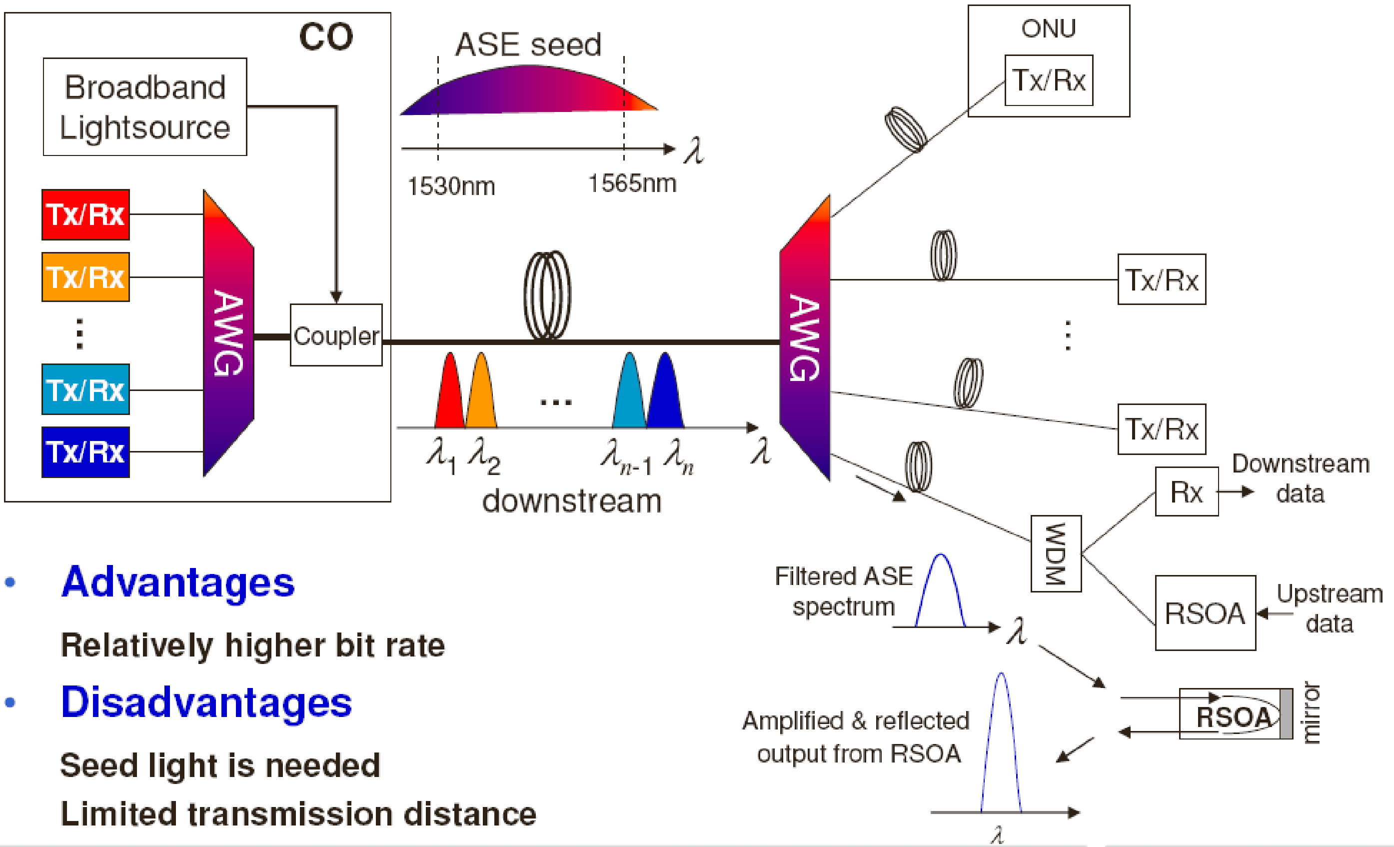
  Seed light is needed

  Limited bit rate and transmission distance

HUAWEI TECHNOLOGIES CO., LTD. Page 11 HUAWEI

Source: Huawei 2010

Reflective Semiconductor Optical Amplifiers



- **Advantages**

  Relatively higher bit rate

- **Disadvantages**

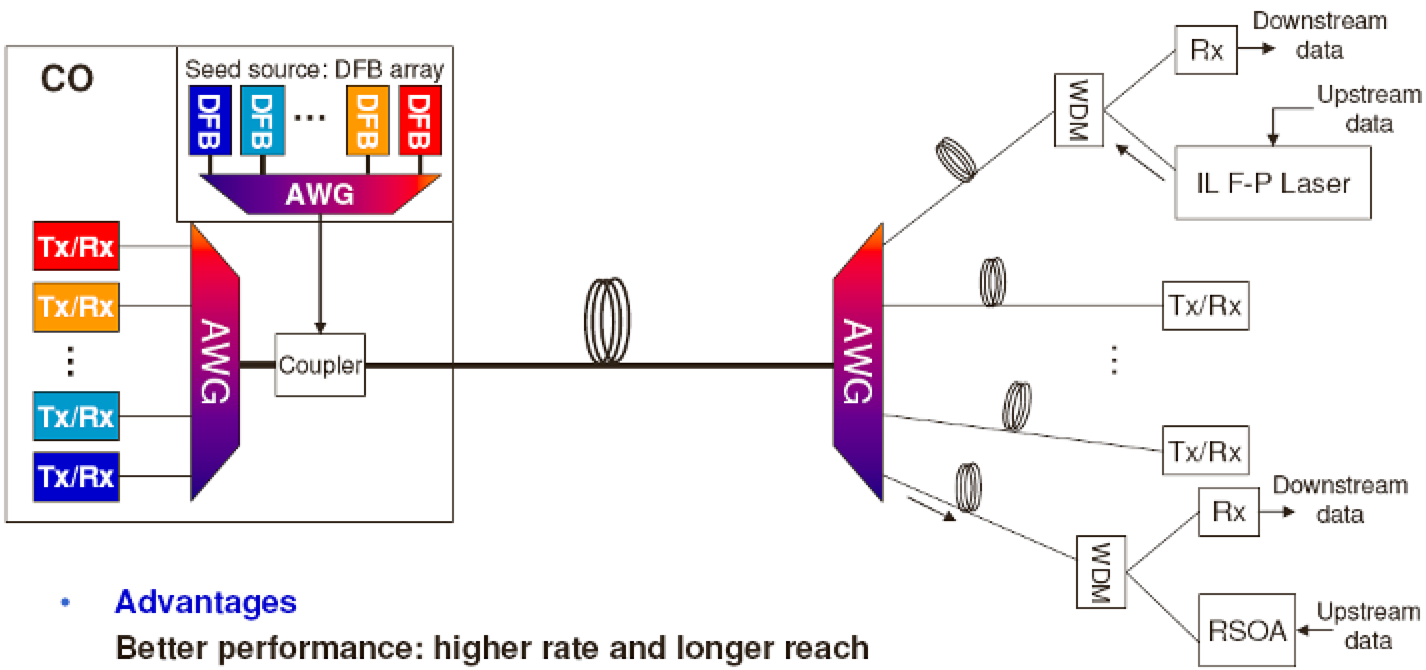
  Seed light is needed

  Limited transmission distance

HUAWEI TECHNOLOGIES CO., LTD. Page 12 HUAWEI

Source: Huawei 2010

Coherent Injection



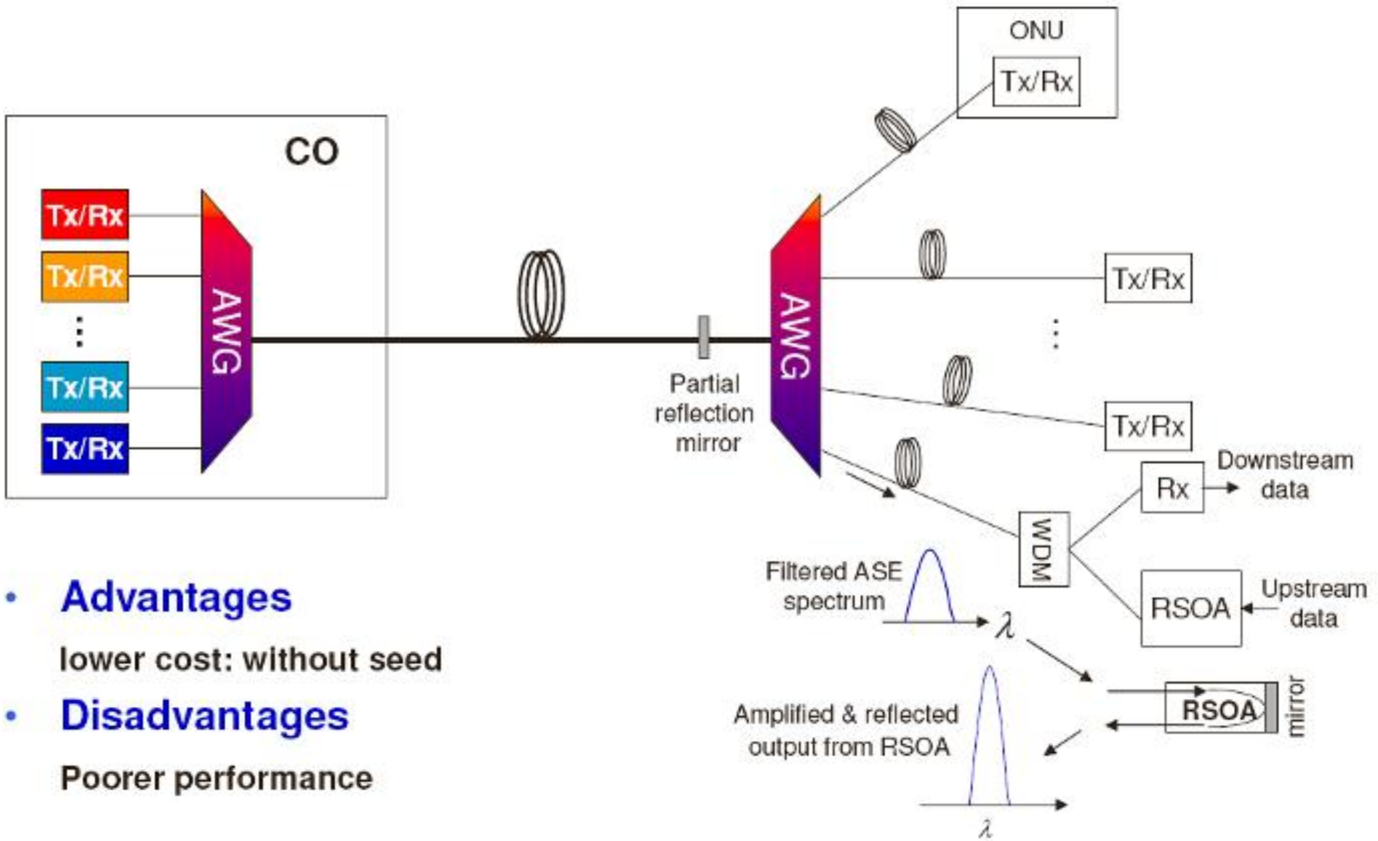
- **Advantages**
  Better performance: higher rate and longer reach
- **Disadvantages**
  DFB array is more expensive than broadband lightsource

HUAWEI TECHNOLOGIES CO., LTD. Page 13 HUAWEI

Source: Huawei 2010

WDM PON Solution 6: Self Seeding

Self Seeding



- **Advantages**

  lower cost: without seed

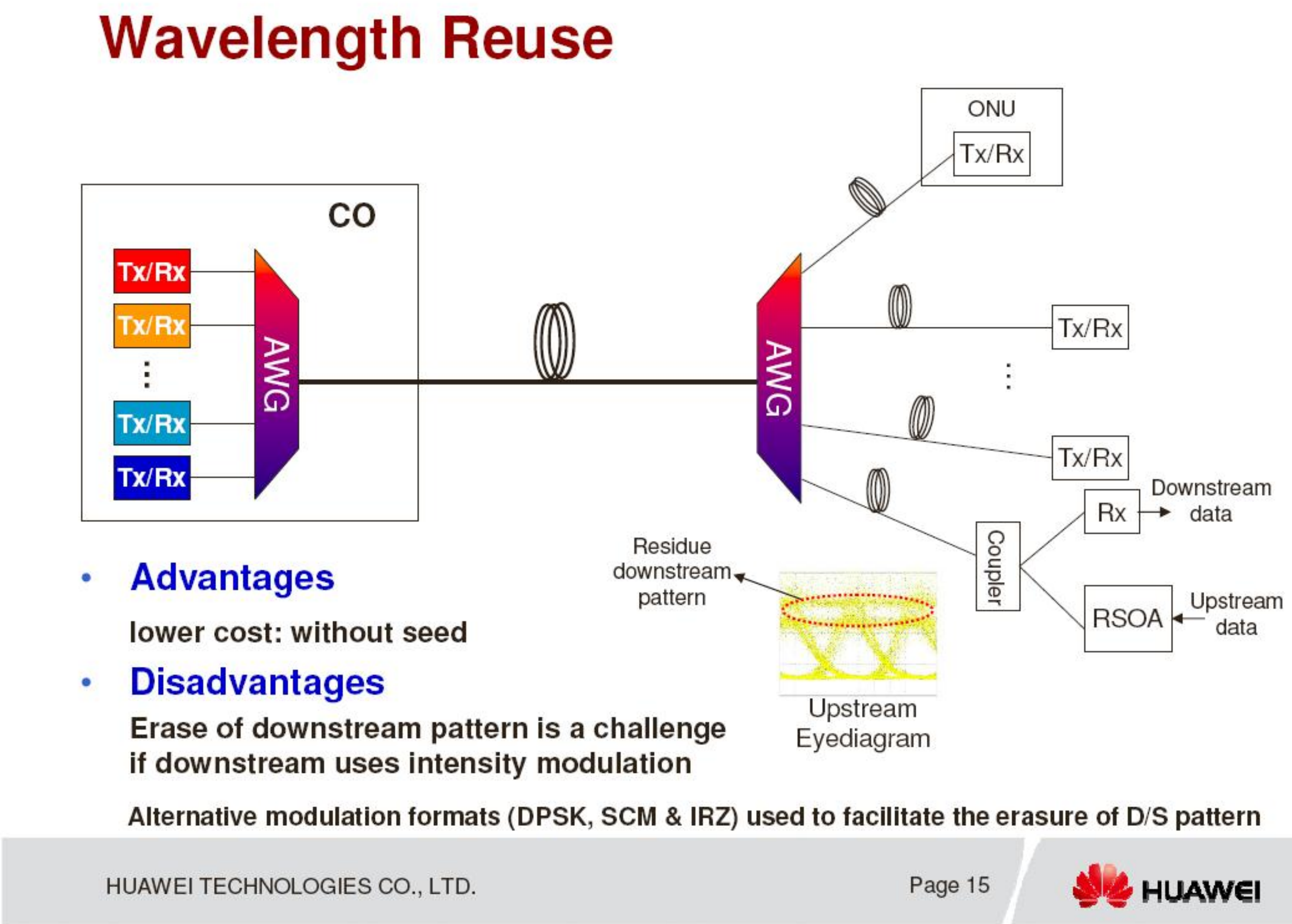
- **Disadvantages**

  Poorer performance

HUAWEI TECHNOLOGIES CO., LTD. Page 14 HUAWEI

Source: Huawei 2010

WDM PON Solution 7: Wavelength Reuse



Source: Huawei 2010

WDM PON Testing Requirements

- Similar Testing compared to classic medium/Long haul WDM networks
  - *Fiber Installation*
    - Classical OTDR (1310/1550nm with macrobend detection), test done from the WDM location if WDM in outside environment, this to test both sides of the network: from Central Office (CO) to WDM and from WDM to customer premises
  - *System Turn-Up*
    - If no available source, tunable source
    - C/DWDM channel checker or Optical Spectrum Analyser
  - *Troubleshooting*
    - C/DWDM channel checker or Optical Spectrum Analyser (OSA)
    - OTDR
      - Out of band 1650nm OTDR to test individual customer (and between MUX/DEMUX in case all customers are affected)
      - 1550nm OTDR to test between CO and WDM as all customers are affected)
      - If CWDM channels used: CWDM OTDR, however not recommended as highly expensive and does not bring much value compared to combination of OSA and classical OTDR.
      - Tunable DWDM OTDR not recommended as highly expensive and does not bring much value compared to combination of OSA and classical OTDR. However could be developped as JDSU owns/designs all the components.
  - *Monitoring*
    - Out of band 1650nm OTDR if channel available on WDM, or 1550nm OTDR with bypass or dark fiber

Challenges in FTTH networks

OPEX and CAPEX Challenges	• Fiber plant and costly network components becoming damaged • Cost of training / re-training • Expensive re-rolls for troubleshooting
Constraints	• Large amount of fiber optic connectors, splices etc… to be tested - Fibers are installed in a harsh environment • Not enough fiber experts • Open networks with different networks and service providers
Impacts	• Poor installation - Difficulties with rollout of FTTH networks • Failing to turn up customer services • Service failures due to customer churn and network evolutions