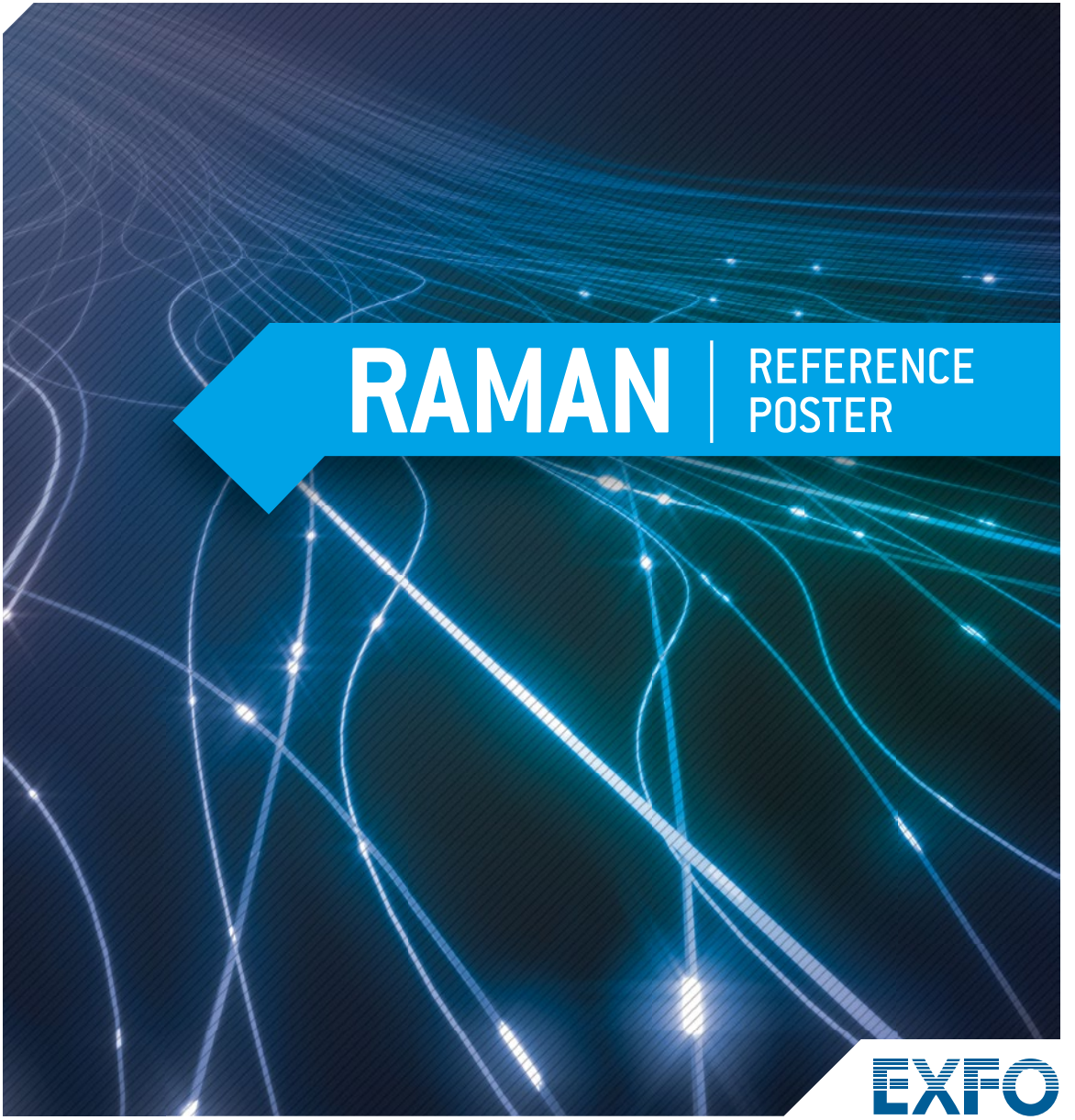
RAMAN
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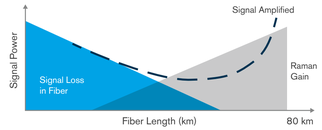
Optimization of Raman Deployments

The quest for paramount bandwidth in optical backbone networks seems never ending. More bandwidth, longer routes and further reach are always desired. From an optical reach/capacity performance perspective, Raman optical amplifiers are superior to EDFAs for three fundamental reasons:

- Their superior noise performance leads to a higher optical signal-to-noise ratio (OSNR) at the output end of the optical path
- Raman optical amplifiers create distributed optical amplification inside the line fibre, mitigating the nonlinear effects experienced by the optical WDM channels
- Raman amplifiers offer broader spectrum than EDFA amplifiers—100 nm with Raman amplifiers while the typical EDFA spectrum is approximately 36 nm

Benefits of Raman Deployment

- Longer fiber spans
- Higher capacity
- Increased link distance
- Enhanced operating margins
- Uses deployed transmission fiber
- Low noise figure



When signal is weak power increases before reaching next EDFA.

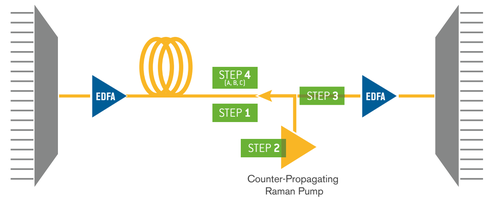
Steps to Optimize Raman Deployments

STEP 1 — VALIDATE FIBER TYPE

STEP 2 — ADJUST PUMP GAIN

STEP 3 — INSPECT AND CLEAN CONNECTORS

STEP 4 (A, B, C) — PREVENT REFLECTIONS, FIBER BENDS AND FIBER LOSS



STEP 1 — VALIDATE FIBER TYPE

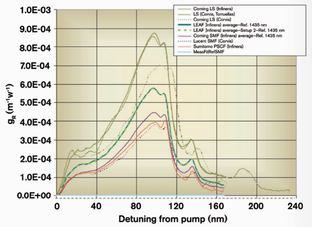
Pump Power

Raman pump power levels must be optimized per fiber type to achieve:

- Optimum gain
- Spectral gain flatness

Adjust pump power to achieve optimal gain. Gain depends on power density, specifically:

- Effective area
- Fiber type



Measure Chromatic Dispersion Parameters to Determine Fiber-Type

Fiber Type	Lambda Zero	Dispersion at 1550 [ps/[nm*km]]	Slope at 1550 nm [ps/[nm*nm]*km]
Standard single-mode	1300-1324 nm	16-18 (17 typical)	~0.056
Corning LS	~1570	–3.5 to –0.1 (–1.4 typical)	~0.07
Dispersion Shifted	~1550	~0	~0.07
True Wave Classic	~1500	0.8-4.6 (2 typical)	~0.06
True Wave Plus	~1530	1.3-5.8	
True Wave Reduced Slope	~1460	2.6-6 (4 typical)	<0.05 (0.045 typical)
Corning E-LEAF	~1500	2-6 (4 typical)	~0.08
Alcatel Teralight	~1440	5.5-9.5 (8 typical)	~0.058
True-Wave Reach	~1405	5.5-8.9 (7-8 typical)	<0.45

FTB-2 and FTB-500 platforms featuring the FTB-5700 Single-Ended Dispersion Analyzer

- PMD and CD measurements for all types of networks
- Fully automated, highly intelligent interface
- One test solution for all dispersion testing
- Single-ended testing of multiple links from one location

- Complete chromatic-dispersion characterization
- Highly accurate phase-shift method
- No communication between source and receiver
- Compliant with TIA-FOTP-169 standard
- Patented design: test through EDFAs

FTB-5800 Chromatic Dispersion Analyzer

STEP 2 — AJUST PUMP GAIN

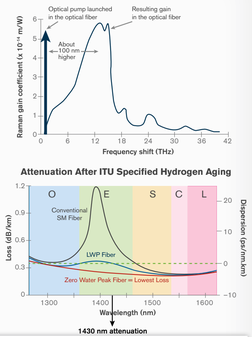
Pump Attenuation

Raman amplification occurs approximatively 100 nm above the pump wavelength.

- Pump: 1430 – 1465 nm*
- Amplification: 1530 – 1565 nm*

** In the waterpeak influence area*

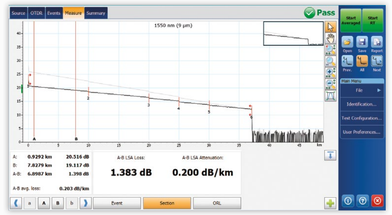
Different fiber types will have different 1430 nm attenuation, and therefore different pump reach and gain efficiency values.



Impact on System Reach

Assume older fiber with average loss in 1450 nm range of 0.33 dB/km	0.05 dB higher loss at pump wavelengths	4 dB less Raman gain	28 % shorter link distance

Results Obtained with a 1430 nm OTDR



FTB-2 platform featuring the FTB-7400E OTDR

- Industry-leading linearity of ±0.03 dB/dB
- Event dead-zone of 0.8 m and attenuation dead zone of 4 m
- Low-water-peak fiber testing at 1383 nm
- Dynamic range of up to 42 dB for long-haul testing

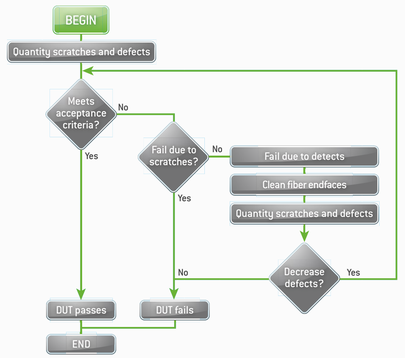
STEP 3 — INSPECT AND CLEAN CONNECTORS

Connector Cleanliness

High power leads to permanent damage to connectors on DWDM equipment and on patch panels.

Figure 1. Functional, clean connector

Figure 2. Permanently damaged connector due to uncleanliness



FIP-430B Fiber Inspection Probe

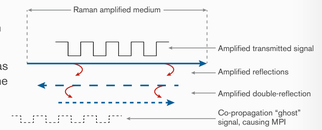
- Automatic image-centering function
- Automatic focus adjustment and optimization
- Automatic pass/fail analysis

STEP 4 (A, B, C) — PREVENT REFLECTIONS, FIBER BENDS AND FIBER LOSS

A) Reflections

Amplification is not uni-directional, so reflection as well as double-reflections will be amplified.

This creates a co-propagation "ghost" known as Multipath interference (MPI) which degrades the quality of the signal.

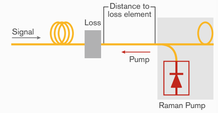


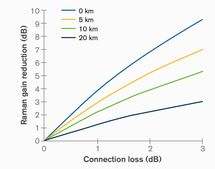
B) Fiber Bends

- Most Raman gain occurs within the first few first km after pump launch
- High power density can cause damage
- Ensure no micro/macrobends are present in the first 20 km (including patchcords)

C) Fiber Loss

- Most Raman gain is achieved within the few first km after the pump launch
- Fiber loss and attenuation at this point is critical
- Connector loss in proximity to Raman pump has maximum impact on Raman gain
- Connector-loss located beyond the "effective length" of the fiber has minimal affect on reduction of Raman gain





Intelligent Fiber Characterization with EXFO's iOLM

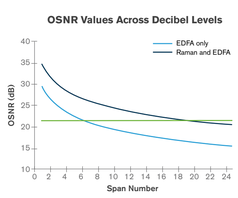
iOLM | Intelligent Optical Link Mapper

- Multi-pulse technology for repeatable and accurate test results
- Straight-forward results with clear icons and pass/fail status
- Self-setting device that optimizes the test parameters
- Comprehensive diagnosis to guide technicians to fix the fault faster

Result of Effective Fiber Testing Process

Multispan link with EDFA amplification

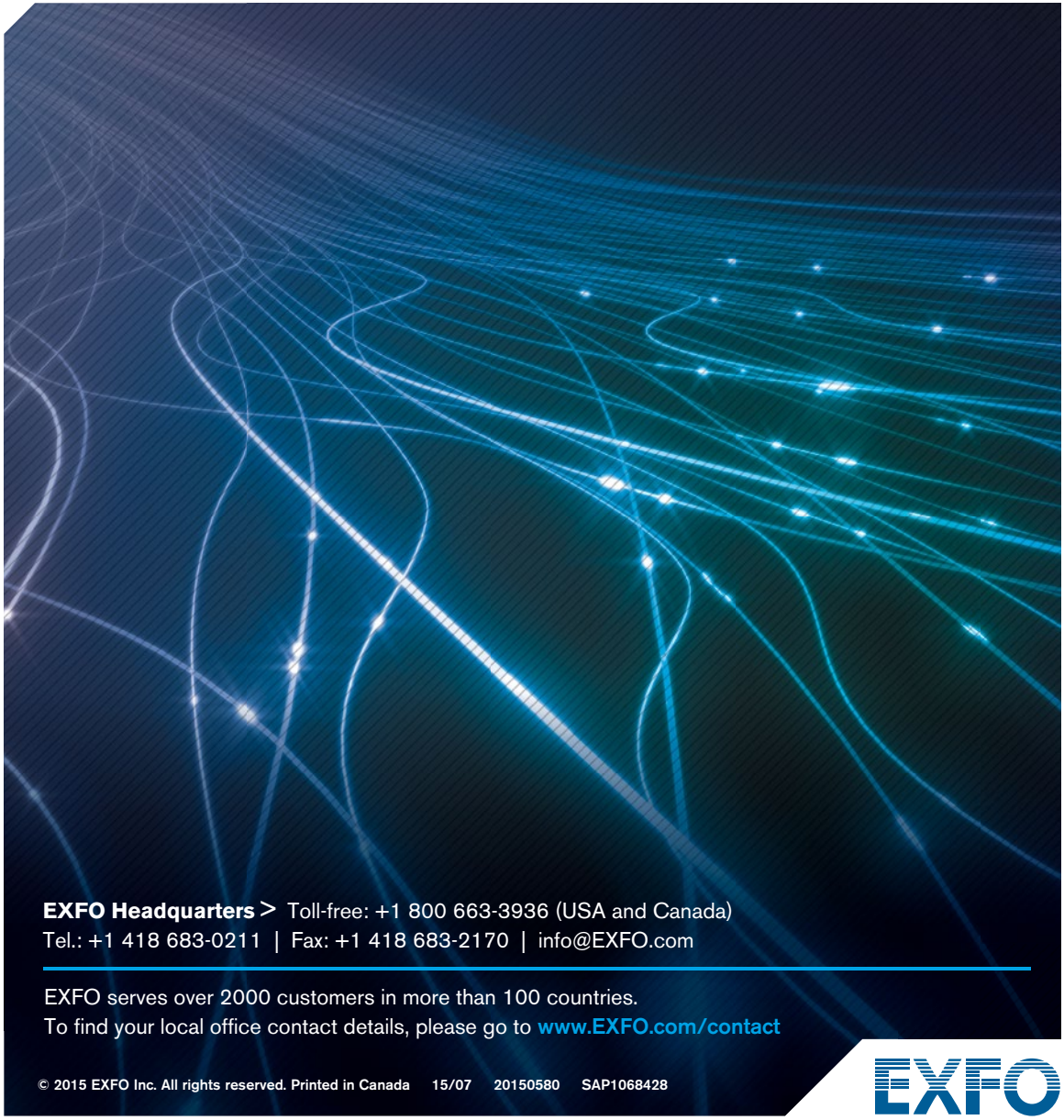
Mulitpsan link with both EDFA and Raman amplification



- Increased signal-distance for a given OSNR value
- Improved OSNR margin over a given distance

EXFO Connect

EXFO Connect's cloud-based solution seamlessly links EXFO instruments and centralizes captured data from steps 1-4 above, sharing it across an organization for complete Raman deployment evaluation.



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