White Paper

Use Remote Integrated iOTDR Intelligence to Ensure Optimal Effects of EDFA and Raman Amplifier in DWDM Networks

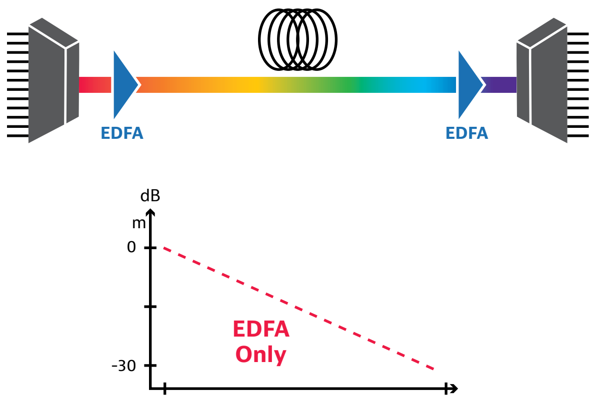
Design considerations

Implement reliable, high speed DWDM networks using integrated iOTDR with Raman Amplifier

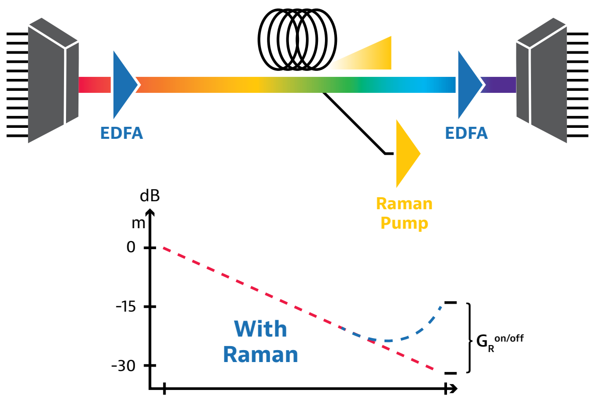
Raman amplifier is a critical technology for enabling reliable optical communication networks. Raman amplifier is extending from long-haul networks into dense wavelength-division multiplexing (DWDM) networks due to massive bandwidth demand. This whitepaper details the considerations for deploying Raman amplifier in DWDM networks and why using an integrated iOTDR in the network element can enable long term success of this economical application.

Why Use Raman Amplifier and How it Works?

Raman amplifier has proved beneficial for applications in 100G network and above that are commonly required in DWDM and the fiber sections of wireless 5G networks. It helps meet the need for higher transmission capacity. Alternatives exist to enhance network transmission capacity, such as extending beyond the C-band into the L-band, increasing the symbol rate or increasing spectral efficiency. All options require a higher optical signal-to-noise ratio (OSNR). Raman amplifier generally offers higher OSDR required to increase capacity, while eliminating the need for expensive opto-electronic regeneration.



Signal power vs. distance with EDFA only



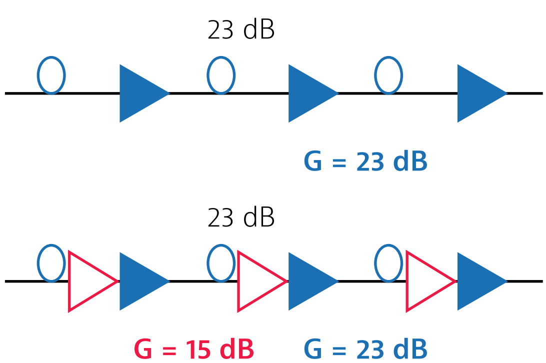
Signal power vs. distance with EDFA and Raman amplifier

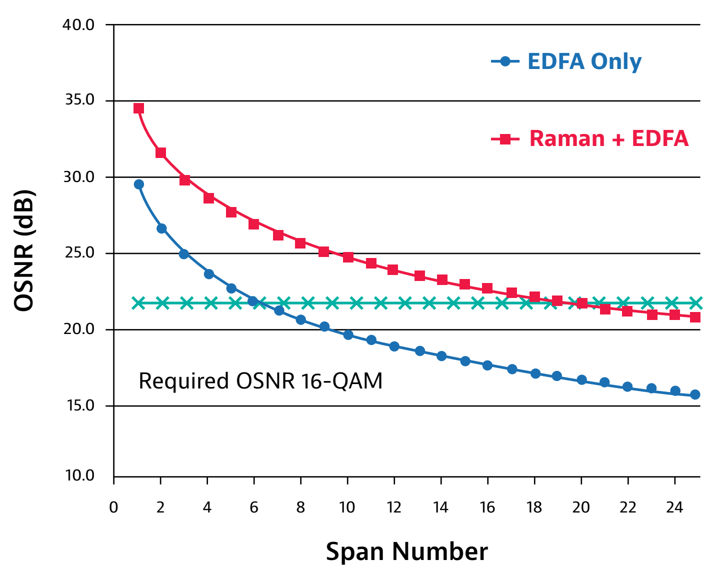
Raman amplification generally leverages the network fiber as the gain medium. By adding a distribution Raman amplifier to a fiber span with EDFAs (Erbium Doped Fiber Amplifier), signal power loss can be decreased. The commonly deployed counter-propagating Raman amplifier consists of one or more Raman pump lasers and a wavelength combiner, so that the Raman pump wavelengths are transmitted into the fiber in the opposite direction of the signal. Signal propagating along the fiber will be attenuated, but as it moves along toward the fiber end where the Raman pump is located, it will start to experience some gain from the Raman pump wavelength. The higher power in the signal thus increases OSNR, which enables longer fiber span, higher capacity and spectral efficiency, and longer link distance.

Solutions for Extending DWDM Reach with Raman Amplifier

EDFA is the default amplifier for use in DWDM transmission and Raman amplification is effective in complementing the EDFA for transmission distance expansion reach in the optical network. Performance improvements can be obtained by combining the two that cannot be accomplished by EDFA alone. The additive reach of combined EDFA and Raman amplifier application in DWDM networks are illustrated on a simplified multi-span link below.

Consider the effect of Raman amplification on a multi-span link with 23 dB loss per span compensated by 23 dB of amplification. In one case, each span loss is compensated with an EDFA, while in the other case, the gain is divided between the distributed Raman amplifier and the EDFA. In the application of hybrid EDFA/Raman amplification, the OSNR curve has shifted upwards towards higher OSNR values to deliver an improved signal transmission capability. The link can obtain higher OSNR for the same span number, or the same OSNR for a much larger span number. The combined EDFA and Raman amplifier in DWDM networks enables a more robust link, with greater margin available for future repairs, noise, or loss changes along the link. All links degrade over time, thus new links should be planned to have excess margin and old links with ONSR issues could potentially utilize the addition of Raman amplifier as a remedial method vs. ripping and replacing the link.





What Are the Real-World Deployment Considerations for Raman Amplifier?

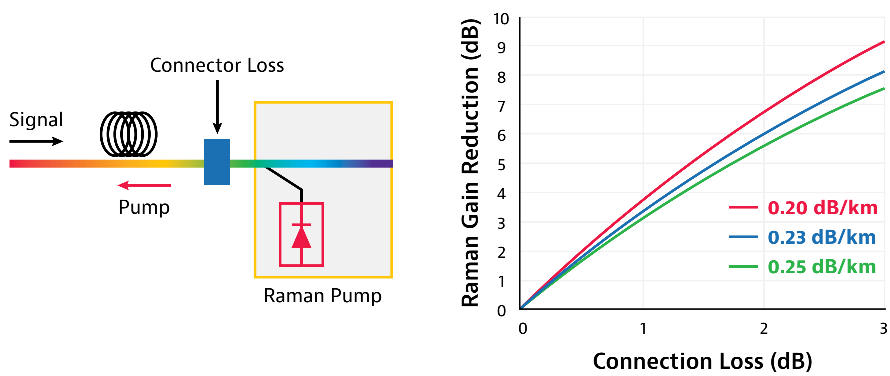
It is important to understand and mitigate risks to realize the potential benefits of adding Raman amplifier to your network.

Fiber Hygiene Is Critical, Including IBYC (Inspect Before You Connect)

The Raman amplifier equipment needs to be connected to the network fiber with minimum connection loss. Such loss is caused by all the usual suspects: contamination like microscopic dirt or oil and misalignment/loose connections can cause reflectance and transmission errors that generate fiber attenuation to produce robust performance and to avoid link degradation. This is the number 1 source of network problems. A VIAVI fiber inspection microscope, such as the p5000i or FiberChek provide for fool-proof inspection before connection.

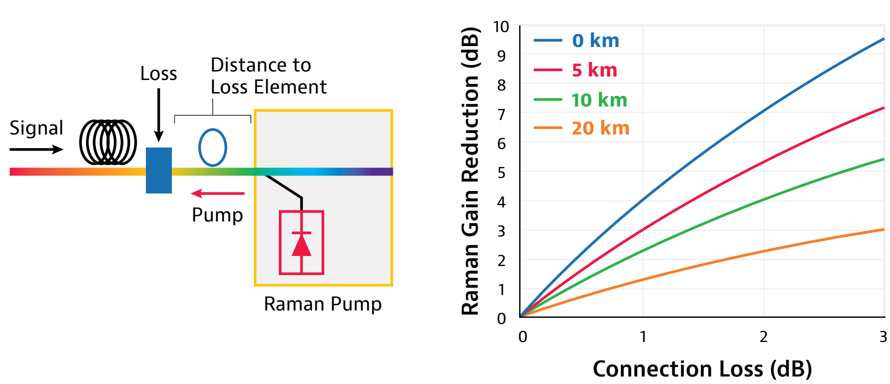
Connection Loss Impacts the Entire Network

The following picture shows the reduction in Raman gain due to different connector losses when the connector is located very close to the Raman pump. The three curves correspond to different fiber attenuation levels at 1550 nm. In this example, a Raman amplifier with a net gain of 15 dB is involved, a 1 dB connection loss can result in a 4 dB gain reduction, and a 2dB connection loss increases the reduction in Raman gain to 7 dB.



Optimize the Location of the Raman Amplifier Pump near the Loss Causation Element

The closer the loss causation element is from the Raman Pump, the less gain is obtained from the amplifier. The location of the loss causation element is strategic and thus planning network topology is an important step. The result can be tested using OTDR to verify the desired results. The figure below shows the Raman gain reduction according to different position of the loss elements, at 0 km, 5 km, 10 km and 20 km away from the Raman pump. It reveals that the Raman gain reduction is lower if the connection loss is located further away from the Raman pump. This is because most of the Raman gain occurs close to the Raman pump. We conclude that most of the gain obtained through Raman amplification is obtained in the region of the effective length of the fiber, which is in the ~20km range.



Integrated OTDR

What is an OTDR?

An Optical Time Domain Reflectometer (OTDR) is a fiber optic tester for the characterization of fiber and optical networks. The purpose of an OTDR is to detect, locate, and measure events at any location on the fiber link.

One of the main benefits of an OTDR is that it operates as a one-dimensional radar system, allowing for complete fiber characterization from only one end of the fiber. The resolution of an OTDR is between 4 centimeters and 40 meters. Selecting the right OTDR for the link is important. Higher resolution OTDRs offer more power, more advanced pulse techniques and computational algorithms and many wavelengths are available depending on the link traffic.

Geographic information detecting localized loss and reflective events is generated using the OTDR, providing technicians with a pictorial and permanent record of the fiber's characteristics at the time of measurement such as the event trace map below. This is used to establish the fiber's performance baseline.

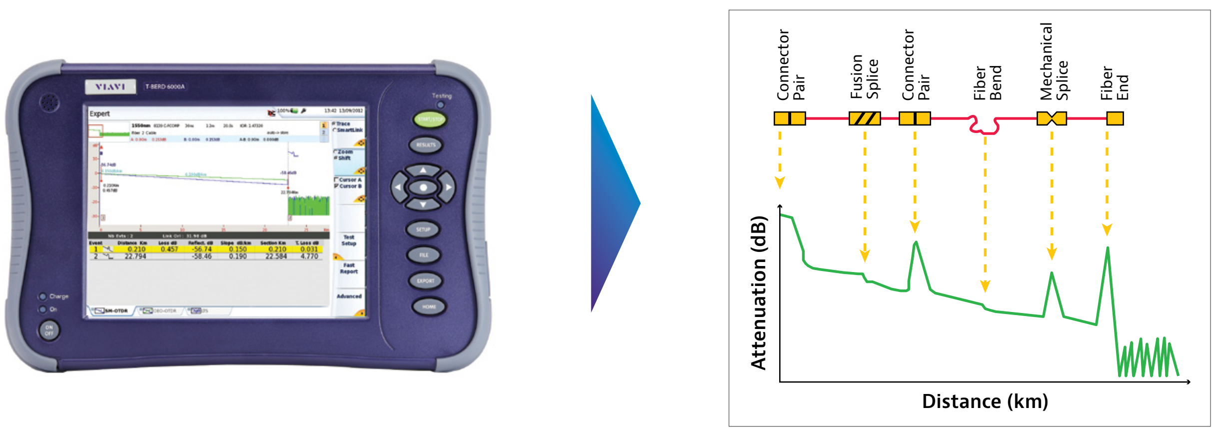
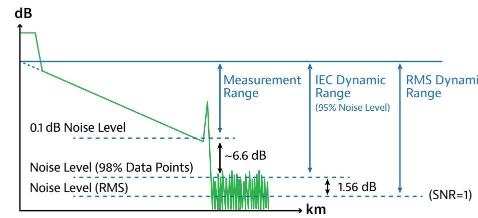


Figure: OTDR and OTDR Trace. The above example shows the results of an OTDR trace with the detection, location and identification of several faults.

OTDR Specifications

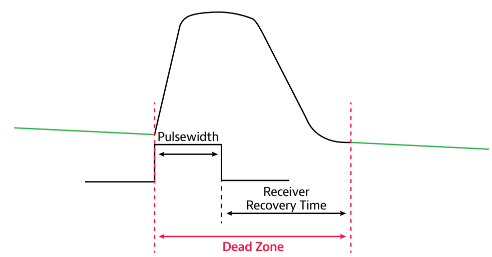
Dynamic Range

The dynamic range determines the maximum observable length of a fiber. Therefore, it also determines the OTDR suitability for analyzing any specific network. The higher the dynamic range, the higher the signal-to-noise ratio and the better the trace resolution is for event detection. The dynamic range is relatively difficult to determine since there is no standard computation method used by all manufacturers.



Dead Zone Limitations

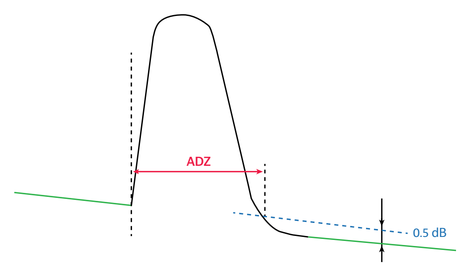
An OTDR is designed to detect the backscattered level all along the fiber link. It measures backscattered signals, which are much smaller than the signal that was injected into the fiber. When there is a strong reflection, the power received by the photodiode can be more than 4,000 times higher than the backscattered power, saturating the photodiode. The photodiode requires time to recover from its saturated condition.



Attenuation Dead Zone (ADZ)

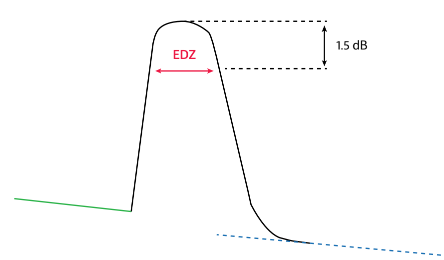
The attenuation dead zone, defined in the IEC 61746 standard for a reflective or attenuating event, is the region after the event where the displayed trace deviates from the undisturbed backscatter trace by more than a given vertical value DF (usually 0.5 dB or 0.1 dB).

The attenuation dead zone depends on the pulse width, the reflectance value of the first reflective event, the loss of this event, and the distance location. It usually indicates the minimum distance after a reflective event where a non-reflective event, a splice for example, can be measured.



Event Dead Zone (EDZ)

For a reflective event, the event dead zone is defined as the distance between the two opposite points that are 1.5 dB (or FWHM) down from the unsaturated peak of a single reflective event.



Dynamic Range, ADZ and EDZ must be carefully checked when an OTDR is selected to qualify RAMAN installation. In the case of an integrated iOTDR, the OTDR is stationary and automated. Thus, the dynamic range of the OTDR must be optimized for the distance in the network design from the OTDR to the end of the link section that one desires to test. Otherwise, fiber faults affected by the RAMAN gain will not be detected. If the range is too short, part of the line will be unmapped due to an ADZ. If it is optimized for a very long distance on a short link, typically the pulse will be too powerful causing an EDZ.

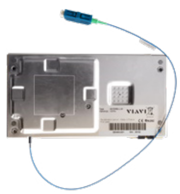
What is an integrated OTDR or iOTDR and how does it compare to other options?

The most common OTDR form factor is a portable OTDR with a touch screen. Rack-mounted OTDRS are used for permanent remote-controlled monitoring and centralized tests that yield network analytics. They have an integrated switch to test many fibers, remote control mobile applications, significant processing power, with the ability to produce network analytics in an accessible database.

T-BERD 6000A
Portable OTDR

OTU-5000 Fiber Test Head

OTU-8000 Fiber Test Head



Micro integrated OTDR card
for long range application

Micro OTDR card integrated
in customer equipment

Nano integrated OTDR card
for medium range application

The Integrated iOTDR cards form factor are embedded within transmission equipment known as network elements.

Because integrated iOTDR cards are fully operated from network equipment, they do not need extra hardware or software or a separate rack/power supply to work. They are designed to run OTDR measurement on fiber carrying data with optical amplification. This feature requires at least additional component for portable or rack mounted OTDR. It enables continuous monitoring of the fiber attenuation.

The footprint of the iOTDR takes up next to no space under tight network conditions and is an economical solution for this purpose. The iOTDR is optimized for either long haul or medium haul links that require amplification to overcome attenuation on longer fiber links that are typical in the metro ring and long core of the network or used for the Data Center Interconnect (DCI) links between data centers.

Fiber or Raman amplifier installation qualification

As the network is built or modified with Raman amplifiers, the iOTDR can characterize the network loss and ensure the expected design is within tolerance of the optical budget required. During installation of the Raman amplifier, conduct a measurement to confirm the fiber performance meets the criteria to optimize Raman gain.

Continuous link monitoring for transmission problems

Automated monitoring can be conducted through routine traces compared to the initial baseline fiber performance against the current performance to ensure the network has not degraded and the Raman gain remains optimum. Networks experience stress from human handling while connections are added/dropped/changed and natural inclement conditions. The iOTDR alarms when conditions risk causing transmission loss as the network degrades or a sudden loss event occurs.

Key Application Use Cases

- Fiber characterization
- Raman amplified link test
- Fiber monitoring
- Fault demarcation
- Tapping security intrusion detection
- Track fiber degradation for preventative maintenance

Requalification for wavelength channel plan upgrade

Finally, there are millions of links in service today that began service under CWDM plans. Narrower DWDM channel plans have increased useful bandwidth, but they can present new noise challenges and higher transmission speed links are more sensitive to fiber faults. The iOTDR provides engineers with the confidence to rapidly upgrade the network wavelength plan while avoiding time consuming travel and handling that is required when using a portable OTDR.

Conclusion

Raman amplifiers are rapidly expanding because they offer higher OSNR required to increase capacity, while eliminates the need for expensive opto-electronic regeneration.

Raman amplifier gain is only optimized if the fiber attenuation is low along the first kilometers. To ensure low fiber attenuation an OTDR is required to localize dirty connector, bad splice or bending affecting fiber attenuation and consequently interfering with expected Raman amplifier gain.

Integrated OTDR is the most appropriate OTDR for checking fiber attenuation during installation and the whole life of Raman amplifier. It is fully integrated with network equipment and optimized to run OTDR measurements on fiber carrying data with optical amplification.

Go to viavisolutions.com or more information on VIAVI iOTDR Micro and Nano Cards.

Source: http://www.fiber-optic-solutions.com/extend-dwdm-reach-raman-amplifier.html

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