VIAVI Solutions

White Paper

Is there a need for 1490 nm testing in PONs?

This paper explains the difference between 1490 nm optical time domain reflectometer (OTDR) and insertion loss testing as well as physical layer and equipment/transmission signal testing. It also describes the technical and economical differences between 1490 and 1550 nm when analyzing the intrinsic characteristics of the fiber.

Point-to-multipoint passive optical networks (PONs), such as Ethernet PON (EPON), Gigabit PON (GPON) or Gigabit Ethernet PON (GEPON) technologies, bring imminent testing challenges, especially at the construction stage of the fiber link when using splitters. The most recurring question concerns the need for qualifying the fiber plant at 1490 nm, the wavelength used to transmit data from the optical line terminal (OLT) to the optical network terminal (ONT), making it legitimate to consider testing at this particular wavelength. But is it worth testing at this wavelength?

OTDR Testing

The OTDR helps technicians characterize fibers and optical networks. Primarily it provides location information regarding localized loss and reflective events, offering a pictorial and permanent record of the characteristics of a fiber. Secondly it measures the total loss of the link, which is discussed later. When characterizing a fiber link, field technicians also measure the insertion loss of the fiber and investigate possible issues that could occur, such as high connector loss, splice loss, high attenuation, or possible bends.

To properly locate an event and measure the reflectance, technicians must enter the fiber specifications into the OTDR setup. Today the International Telecommunications Union-Telecommunications Sector (ITU-T) G.652 standard does not require specification at 1490 nm and most fiber manufacturers provide fiber specifications for the common 1310 and 1550 nm wavelengths. The index of refraction and backscatter coefficient settings for 1490 nm are typically unknown, leaving users unassured of the accuracy of location and reflectance results.

Furthermore, splice/connector losses are not wavelength-dependent. A 0.2 dB splice loss at 1550 nm will exhibit a 0.2 dB loss at 1310 and 1490 nm.

Another key element of a PON system is the splitter (from a 1x4 to a 1x64). The most commonly used is the 1x32 and the loss variation between the 1490 and 1550 nm wavelengths is as low as 0.3 dB. Once again, it shows minimal or marginal value-added information for testing at these two wavelengths.

Also the OTDR can detect and localize macro bends by comparing two OTDR shots made at different wavelengths, typically 1310 and 1550 nm. Longer wavelengths are more sensitive to macro bends, meaning the bend-dependent loss is higher and the location easier.

Figure 1 shows the loss dependency versus wavelength for various bend radii.

Single-mode fibers are more sensitive to bending losses at longer wavelengths, therefore, 1550 nm wavelengths are more sensitive to macro bends than 1490 nm. As the graph shows, a macro bend with a radius of 25 mm will exhibit a high loss at 1550 nm but nothing at 1490 or 1310 nm.

For OTDR measurements, 1490 nm wavelength does not provide additional value in bend detection and may give wrong location and reflectance results on PON systems.

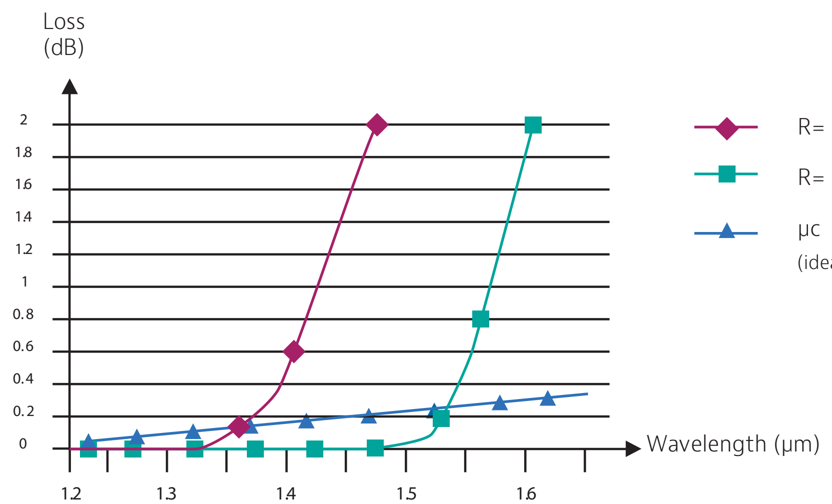

Figure 1. R Radius of curvature of fiber

Insertion Loss Testing

When characterizing a fiber link, field technicians also measure the insertion loss (IL) of the fiber looking for high attenuation.

Figure 2 shows the attenuation characteristics of a fiber according to the wavelength. It shows that the S-band (1460–1530 nm) and C-band (1530–1565 nm) areas are flat, resulting in little difference in terms of attenuation.

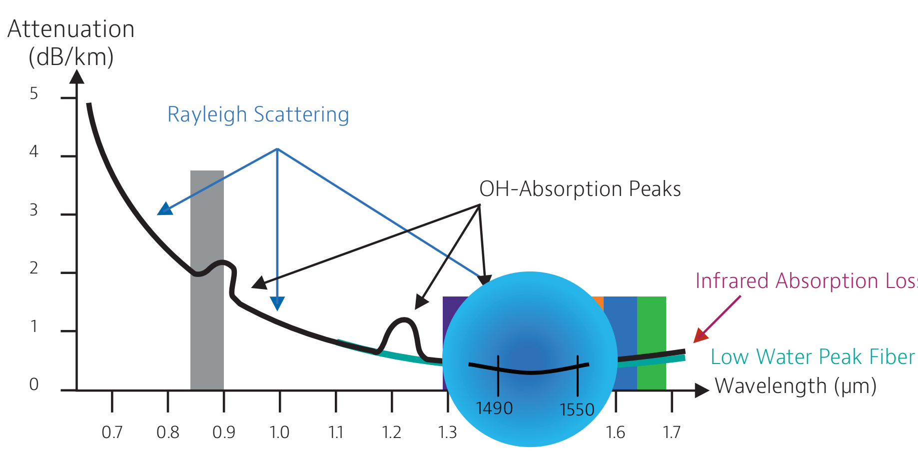

Figure 2. Fiber attenuation as a function of wavelength

Even if some fiber manufacturers give a specification at 1490 nm the example table below demonstrates that measuring insertion loss at 1490 and 1550 nm gives very close results.

Wavelength	Typical Attenuation Coefficient for G.652.C
1310 nm	0.32 dB/km
1490 nm	0.21 dB/km
1550 nm	0.19 dB/km

Table 1. Examples of 1490 nm impact on the total loss

The typical difference between the attenuation coefficients of 1490 and 1550 nm is 0.02 dB/km. The average range for fiber lengths in PONs is 10 km. Hence, the difference in attenuation between both wavelengths is marginal, as shown below.

$IL_{1490\ nm} = 0.21 \times 10 = 2.1\ dB$
$IL_{1550\ nm} = 0.19 \times 10 = 1.9\ dB$
$\Delta_{IL} = IL_{1490\ nm} - IL_{1550\ nm} = 0.2\ dB$

As previously stated, splices, connectors, and splitter losses will not change as a function of wavelength. The only parameter affected is attenuation, but it does not have much affect on short distance such as PONs.

Comparing the insertion loss measurements in a PON system with the configuration described above shows little variation. The measurement below was performed using a calibrated light source and a broadband power meter.

End-to-end PON system insertion loss measurement:

$IL_{1490\ nm} = -\ 23.73\ dB$
$IL_{1550\ nm} = -\ 23.66\ dB$
$\Delta_{IL} = IL_{1490\ nm} - IL_{1550\ nm} = 0.07\ dB$

In summary, the insertion loss difference between 1490 and 1550 nm wavelengths could reach a maximum of ~0.2/0.3 dB, which accounts for up to 1 percent of a total loss of up to 30 dB for the overall system. This difference is only critical if the overall loss budget is tighter than 30 dB for the overall system, which only applies if the measurement uncertainty is far below this value.

Physical Layer and Equipment/Transmission Signal Testing

Testing the physical layer of the network (the passive network elements) during construction before installing equipment will verify that the fiber link meets required performance levels. An OTDR, light source, and power meter will measure the intrinsic characteristics of the optical fiber and splitters to qualify the passive network elements. The test equipment has its own signal source (OTDR or light source) that can emit signals at different wavelengths than the network equipment (OLT) so it can be used prior to network equipment installation and also after activation. Most operators measure the attenuation of the fiber link at historical or common wavelengths, such as 1310, 1550, and eventually 1625 nm or 1650 nm in order to qualify the PON for future Point to Point wavelength division multiplexing (PtP-WDM) and NG-PON2 services operating in the L band.

Once the active network equipment (OLT and ONT) are installed and activated a verification step is performed using an optical power meter to measure the transmission wavelength of the equipment. The behavior of a PON system (i.e. having multiple wavelengths present at the same time) requires a traditional PON selective power meter with 1490, 1310, and eventually 1550 nm capabilities (depending on the wavelength transmitted) and a pass through mode to selectively measure both downstream and upstream signals coming from and going to the OLT. The power meter must be calibrated for the specific wavelengths being tested.

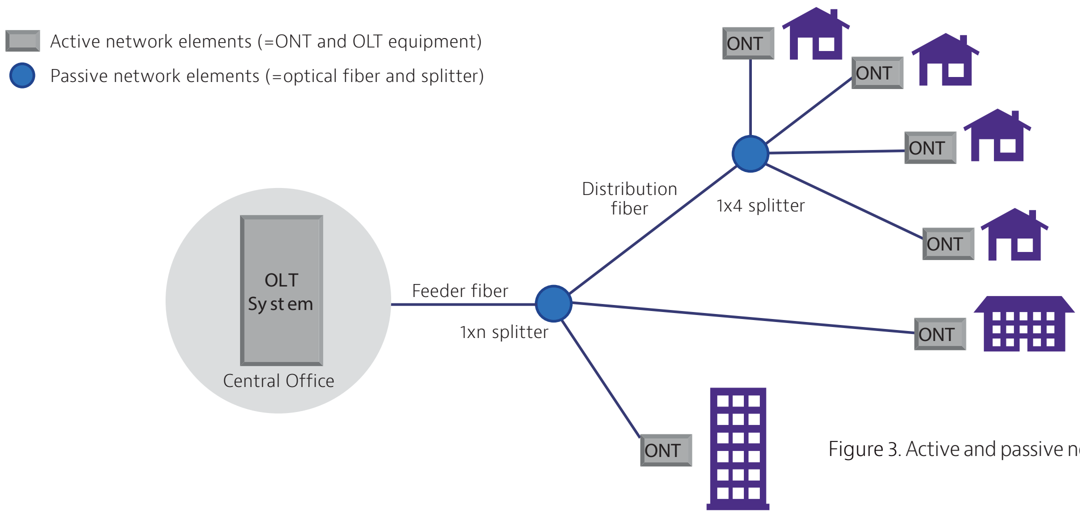

Figure 3. Active and passive network elements

Cost and Operating Expenses to Consider

Historically when budgeting for new test equipment for qualifying PONs, operators purchased common dual-wavelength 1310/1550 nm OTDRs or loss test sets.* Operators who wish to measure transmission wavelengths such as 1310/1550 and 1490 nm must increase their test equipment budget. This is because 1490 nm lasers cost nearly three times that of a 1550 nm laser, primarily because 1490 nm lasers are not commonly deployed in the industry.

Furthermore, standardizing 1310/1550 and 1490 nm OTDRs for test methods and procedures would render previously purchased 1310/1550 nm OTDRs or loss test sets obsolete as they would only be able to test at 2 of the 3 requested wavelengths, thus obliterating past investments, and as we've shown OTDR and loss testing at 1490nm doesn't yield any significant improvements or gains over standard 1310/1550nm testing..

A key driver of fiber-to-the-home (FTTH) deployment is controlling the associated expenses in order to obtain quick returns on investment. Selecting the right OTDR with the right wavelengths will optimize operating expenditures (OPEX) and test equipment costs.

Conclusion

For PON fiber construction and link qualification using OTDRs and/or loss test sets, the traditional 1310/1550 nm wavelength solutions provide equal value as 1490 nm.

Testing at 1490 nm with a PON selective power meter is essential for measuring absolute power levels during network equipment (OLT & ONT) turn-up or troubleshooting.

For years, the largest operators worldwide invested in OTDRs and loss test sets with 1310 and 1550 nm wavelengths capabilities for PON construction and only used a 1490 nm testing solution with a PON power meter for turn-up and troubleshooting.

References

[*] CENELEC, European Committee for Electrotechnical Standardization, "Fibre optic access to end-user—A guideline to building of a FTTX fibre optic network," CLC/TR 50510, 2007.

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