White Paper

Fiber Water Peak Characterization

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Introduction

Many years ago, transmission wavelengths were only around 850, 1310, and 1550 nm; therefore, cable manufacturers designed products to perform best at those wavelengths. Dense wavelength division multiplexing (DWDM) transmission technology pushed to cover larger wavelength bands. Fibers designed for the C+L band (1525 to 1625 nm) transmission are commonly available today, and the use of the S band (1470 to1525 nm) will likely soon follow.

With the advent of coarse wavelength division multiplexing (CWDM) transmission, covering the entire single-mode transmission band from 1271 to 1611 nm calls into question the suitability of installed fiber to properly transmit all wavelengths in this range, especially within the so-called water peak area around 1383 nm.

The International Telecommunications Union (ITU-T) G.694.2 recommendation defines the nominal wavelength grid supporting CWDM systems. Figure 1 shows the coverage of the large wavelength range (from 1271 to 1611 nm) with 20 nm spacing.

Installing or upgrading CWDM equipment in the field requires several steps to guarantee the correct setup of systems so they work error-free when put into service. The first step is ensuring the correct transmission of all wavelengths from end to end, and that the receiver-side power level is within the proper range.

Consequently, testing the fiber physical characteristics is necessary to determine the magnitude of loss in the water peak area, which is the most significantly changing parameter.

Several methods or test solutions can perform this measurement in the field, even after the fiber plant has been installed.

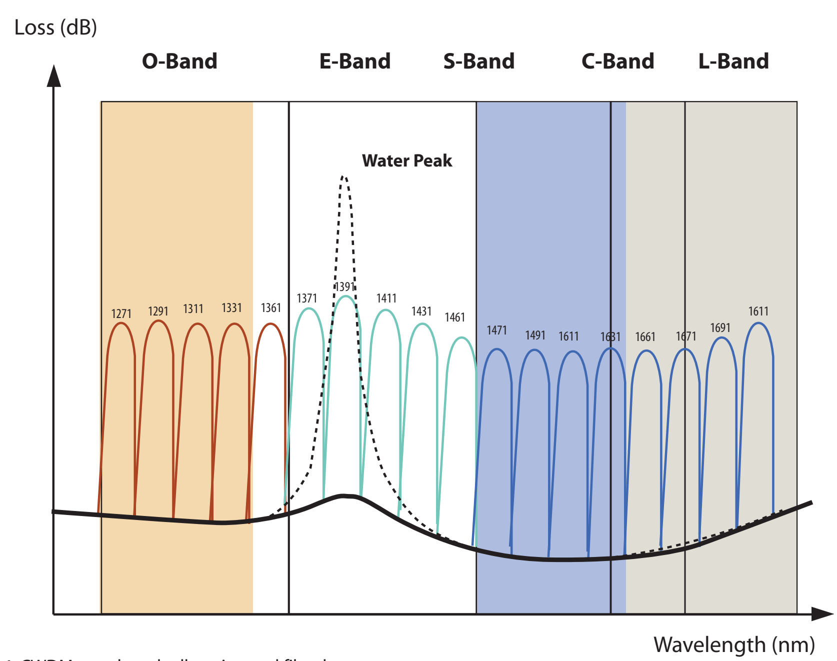

Figure 1. CWDM wavelength allocation and fiber loss

Fiber Attenuation vs Wavelength

Attenuation depends on the fiber type and the wavelength. If the absorption spectrum of a fiber is plotted against the wavelength of the laser, certain characteristics of the fiber can be identified. The graph in Figure 2 illustrates the relationship between the wavelength of the injected light and the total fiber attenuation.

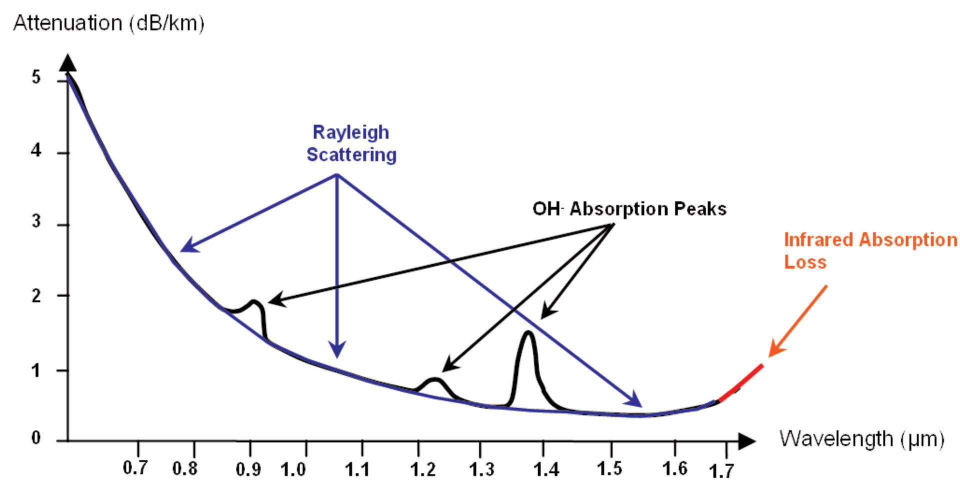

Figure 2. Relationship between wavelength and total fiber attenuation

The main telecommunication transmission wavelengths correspond to the points on the graph where attenuation is minimal. These wavelength ranges are known as the telecom windows.

The OH- symbol identified in the graph indicates that at the 950, 1244, and 1383 nm wavelengths, the presence of hydrogen and hydroxide ions within the fiber optic cable causes an increase in attenuation. These ions occur because water molecules either entered the cable material through a chemical reaction during the manufacturing process or as environmental humidity. The water molecules are known as the water peak absorption areas.

As for the 1383 nm wavelength, it falls into the telecom transmission range yet is not viable for a wide wavelength range transmission, such as CWDM.

Low Water Peak Fibers

For the past few years, fiber manufacturers have worked to minimize the water peak area, allowing for proper transmission, even at wavelengths within the 1383 nm range. These low water peak fibers exhibit a linear attenuation at 1383 nm, closer to the 1310 nm values (for example, 0.35 dB/km) or better as Figure 3 shows. In fact, the loss attributed to OH- absorption is smaller than the loss inherent to the Silica, essentially related to diffusion, which accounts for approximately 0.35 dB/km at 1383 nm.

Examples of this type of fiber include SMF-28e™ from Corning and OFS AllWave™ from OFS.

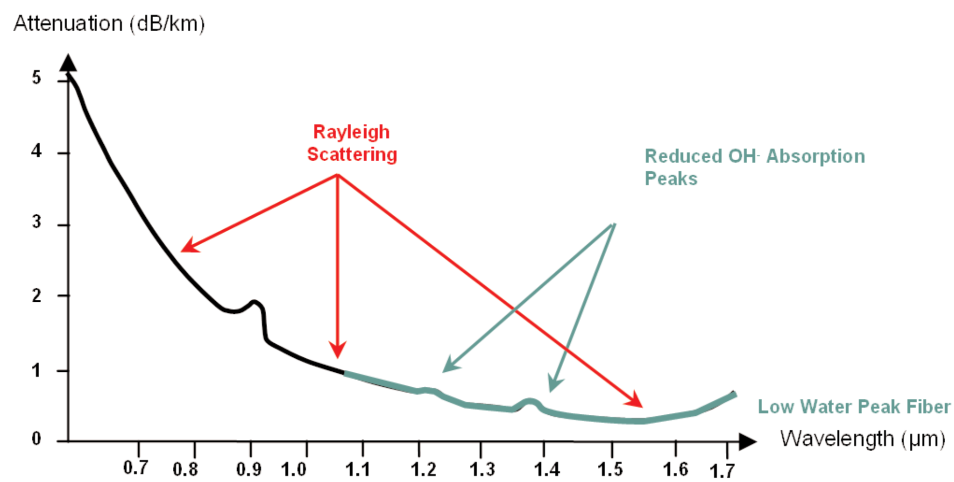

Figure 3. Linear attenuation near the 1310 nm values for "low water peak" fibers

Fiber Differentiation vs. Water Peak Attenuation in a G.652 Single-mode Fiber

The ITU-T has considered the attenuation factor in classifying the single-mode fibers according to their suitability for certain transmission applications. Table 1 provides an example of this classification for the G.652 fiber, considering the wavelength coverage.

	Characteristics	Wavelength Coverage	Applications
G.652.A		1310 and 1550 nm regions (O and C bands)	Supports applications such as those recommended in G.957 and G.691 up to STM-16, 10 Gb/s up to 40 km (Ethernet), and STM-256 for G.693.
G.652.B	Maximum attenuation specified at 1625 nm	1310, 1550, and 1625 nm regions (O and C+L bands)	Supports some higher bit rate applications up to STM-64 in G.691 and G.692 and some STM-256 applications in G.693 and G.959.1. Depending on the application, accommodating for chromatic dispersion may be necessary.
G.652.C	Maximum attenuation specified at 1383 nm (1310 nm)	From O to C bands	Similar to G.652.A, but this standard allows for transmission in portions of an extended wavelength range from 1360 to 1530 nm. Suitable for CWDM systems.
G.652.D	Maximum attenuation specified from 1310 to 1625 nm. Maximum attenuation specified at 1383 nm (1310 nm)	Wide band coverage (from O to L bands)	Similar to G.652.B, but this standard allows for transmission in portions of an extended wavelength range from 1360 to 1530 nm. Suitable for CWDM systems.

Table 1. Classifying single-mode fibers

Identifying Fiber Suitability to Extended DWDM and CWDM Transmission Systems

New fibers complying with the dedicated ITU-T sub-categories can manage the high attenuation near 1383 nm, as shown in Figure 4. Meanwhile, the ability to manage high attenuation for fibers becomes questionable regarding its use in an existing fiber plant, as records rarely exist to support this use.

Network planners and engineers must determine whether the fiber network is compatible with CWDM deployment in the full wavelength range when adding new technologies that will increase the bandwidth capacity of the network and offer additional services to customers.

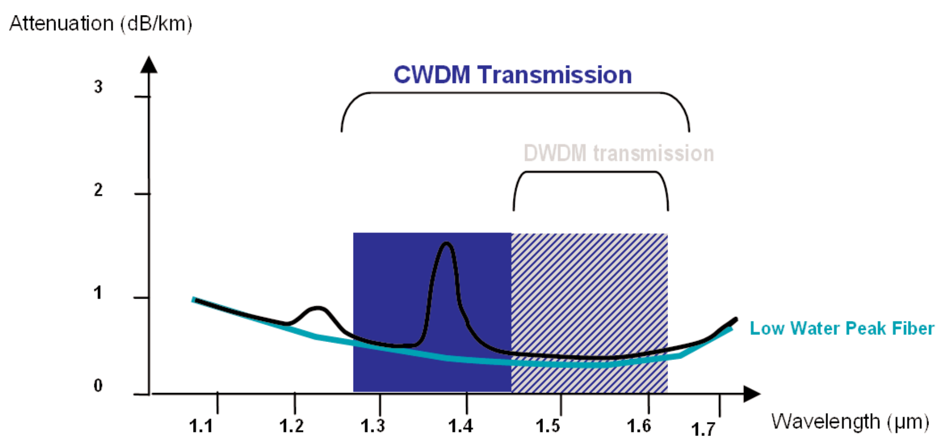

Figure 4. New fibers complying with ITU-T sub-categories manage higher attenuations near 1383 nm

Figure 5 shows two measurements of the attenuation coefficient for fiber around 1383 nm, which was conducted on two fibers from 1995 and 2000, respectively.

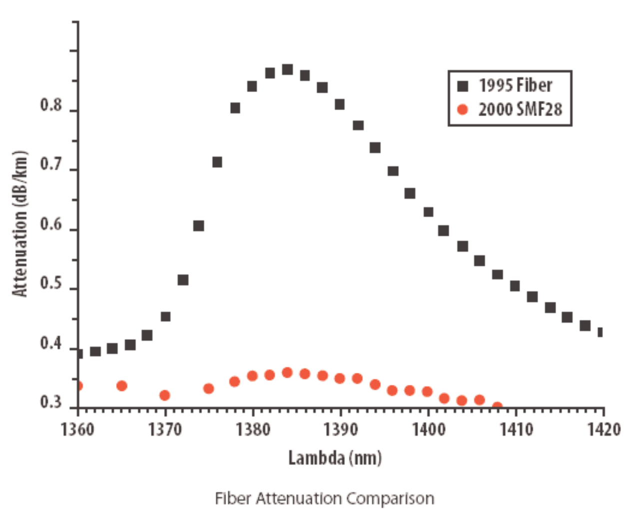

Figure 5. Fiber attenuation comparison

Using an OTDR to Characterize the OH- Absorption Peak

Fortunately, different test solutions enable fiber characterization for absorption peak. Conducting attenuation profile measurements with an optical time domain reflectometer (OTDR) provides comparisons for attenuation vs. wavelength measurements at 1383 nm to determine the magnitude of loss.

OTDR Measurements at 1383 nm

For more than 10 years, OH- concentration was so high in fibers that the 1383 nm wavelength test was impractical (for example, 1 dB/km with a 40 dB dynamic range meant only reached 40 km). An alternative solution used the 1244 nm wavelength, where the attenuation is lower relative to OH. Some OTDR vendors have offered this alternative solution for some time.

Nowadays, the OH- absorption at 1383 nm is lower and lasers testing this wavelength provide higher power output, thus making an OTDR test at this particular point possible. Moreover, this test is highly recommended for reasons that are twofold:

1. The effect of OH- presence is magnified when tested at 1383 nm compared to 1244 nm, providing more accurate analysis.
2. Considering the OH- test for the potential use of the fiber over the CWDM grid or for a Raman pumped network, it is important to know the impact of water at the wavelength for a specific location, or an attenuation magnitude around 1383 nm.

Using this OTDR solution at 1383 nm is advantageous in that this wavelength can be combined to the conventional 1310/1550/1625 nm wavelengths, which provides a more complete picture of the fiber attenuation over the full wavelength range.

JDSU 1383 nm OTDR

Understanding the need for such specific characterization early on, JDSU developed a high performance OTDR suite to give field technicians accurate information that they could provide to network planners and engineers regarding the quality of the fiber at this point.

When testing at this wavelength, technicians can observe the slope of the OTDR trace and interpret the results (Figure 6).

Figure 6. OTDR measurement at 1383 nm with the JDSU VLR module

Characterizing Attenuation vs Wavelength, including the OH- Absorption Peak, with an OSA

Measuring the attenuation profile (AP), or spectral attenuation (SA), provides the ability to plot fiber loss according to wavelength, enabling the characterization of the water peak area with multiple acquisition points. One test method available for measuring the attenuation profile uses the broadband source (BBS) and an optical spectrum analyzer (OSA). Both have a wavelength range equal to or larger than the transmission band.

Test Procedure with the JDSU Solution

At a minimum, JDSU recommends measuring the AP at 1383 nm; However, for DWDM and CWDM transmission systems, it is best to perform full band AP (1261 to 1611 nm), as shown in Figure 7.

Measuring the AP requires a reference measurement prior to performing the tests. Perform the attenuation measurement then subtract the reference values to obtain the actual SA of the link.

AP measurements are performed unidirectionally. Achieving normalized results for distance (attenuation in dB/km) requires dividing the total loss of a given wavelength by the link distance.

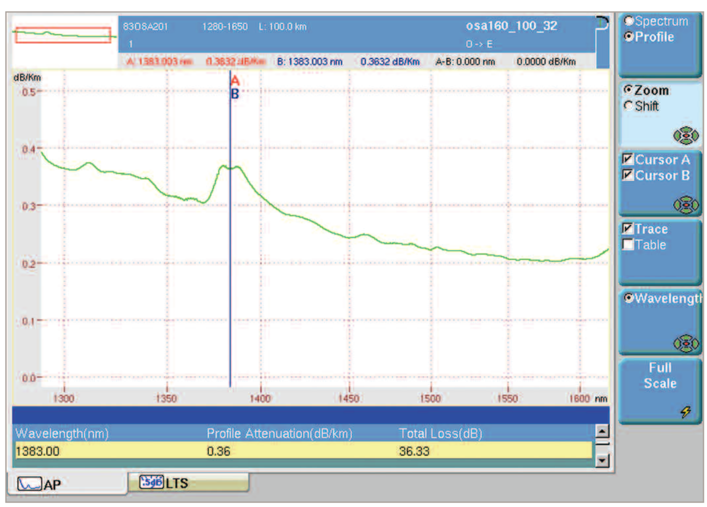

Figure 7. Attenuation Profile measurement with the T-BERD®/MTS-8000 and a full band broadband source (1260 to 1640 nm)

Conclusion

As transmission wavelength ranges broaden and the deployment of various fiber types in the field increase, it becomes critical to more precisely characterize the fibers intended for use. It is imperative to measure the water peak, around 1383 nm, as part of the fiber characterization process (combined with conventional Insertion Loss, OTDR, chromatic dispersion, and polarization mode dispersion), or perform a stand-alone measurement when specific 1383 nm testing is required.

JDSU provides solutions using either the T-BERD/MTS-8000 or the T-BERD/MTS-6000 platforms that cover both DWDM and CWDM applications. The four-wavelength OTDR lets technicians combine the 1383 nm measurement with traditional OTDR test wavelengths (1310/1550/1625 nm), and the optical dispersion measurement module lets them fully characterize the AP of the fiber over the entire wavelength range (1260 to 1640 nm).

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