Spectral Attenuation Measurement in CWDM/DWDM Transmission Links

Introduction

In years past, transmission wavelengths were 850 nm, 1310 nm, and 1550 nm. Fiber optic manufacturers designed their products for best performance at those wavelengths. The advent of dense wave division multiplexing (DWDM) transmission technology pushed to larger wavelength bands coverage, and fibers designed for the C+L band (1525-1625 nm) are now commonly available. The use of the S band (1470-1525 nm) is likely to follow shortly.

With the development of coarse wave division multiplexing (CWDM) transmission, covering the entire singlemode transmission band from 1261 to 1611nm, appeared the problem of suitability of fibers for proper transmission in this entire range, especially within the so called "water peak" region around 1383 nm.

In long distance transmissions, as well as at very high bit rate (10G, 40G systems), Raman amplifications are more and more in use. In addition, new Distal pumping of Erbium amplifiers at 1480 nm are currently deployed. Characterizing fiber at the pump wavelengths (1420, 1450 nm, 1480 nm, etc.) is of high interest to ensure amplification will occur along the required distance.

Because all of these applications make such a broad and varied use of the optical fiber, characterization over the complete useful wavelength is justified rather than characterizing only at discrete wavelengths.

Relevant Standards for Spectral Attenuation Measurements

Types of Singlemode Fiber

There are different types of singlemode fiber, which are classified according to their attenuation range, chromatic dispersion (CD) values, and polarization mode dispersion (PMD) coefficients. The ITU-T has provided a set of standards in order to classify singlemode fibers. Following is a summary of these types of fiber considering the wavelength coverage.

	Characteristics	Wavelength Coverage	Applications
G.652.A	Maximum attenuation specified at 1625 nm.	1310 nm 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 1383 nm (equal or lower than 1310 nm).	1310 nm, 1550 nm, 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, chromatic dispersion accommodation may be necessary.
G.652.C	Maximum attenuation specified from 1310 to 1625 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 nm to 1530 nm. Suitable for CWDM systems.
G.652.D	Maximum attenuation specified at 1383 nm (equal or lower than 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 nm to 1530 nm. Suitable for CWDM systems.

G.652: Characteristics of singlemode optical fiber and cable

	Characteristics	Wavelength Coverage	Applications
G.655.A	Maximum attenuation specified at 1550 nm only.	C bands	Supports DWDM transmission (ITU-T G.692) applications in the C bands with down to 200 GHz channel spacing.
G.655.B	Maximum attenuation specified at 1550 nm and 1625 nm. Higher CD value than G.655.A.	1550 nm and 1625 nm regions (C+L bands)	Supports DWDM transmission (ITU-T G.692) applications in the C+L bands with down to 100 GHz channel spacing.
G.655.C	Maximum attenuation specified at 1550 nm and 1625 nm. Higher CD value than G.655.A.	From 0 to C bands	Similar to G.655.B, but this standard allows for transmission applications at high bit rates for STM-64/OC-192 (10 Gb/s) over longer distances. Also suitable for STM-256/OC-568 (40 Gb/s).

G.655: Characteristics of non-zero dispersion shifted singlemode optical fiber and cable

The G.656 standard is an extension of G.655, but it specifically addresses the wider wavelength range for DWDM transmission over the S, C, and L bands.

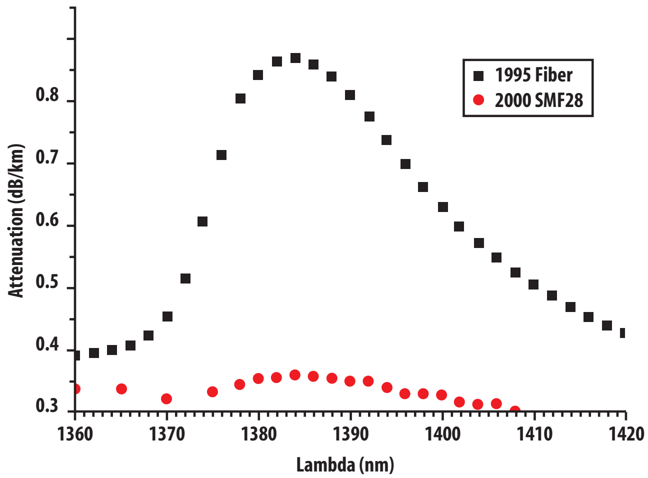
	Characteristics	Wavelength Coverage	Applications
G.656	Maximum attenuation specified at 1460 nm, 1550 nm, and 1625 nm. Minimum CD value of 2 ps/nm.km between 1460 nm and 1625 nm.	S, C, and L bands	Supports both CWDM and DWDM systems throughout the wavelength range of 1460 nm and 1625 nm.

Identify the fiber suitability to extended DWDM and CWDM transmission systems

Recent advances in the manufacturing processes of fiber optic cable have overcome the 1383 nm water peak attenuation constraints and have resulted in "low water peak" fibers. Examples of this type of fiber include SMF-28e from Corning and OFS AllWave from Lucent.

Meanwhile, when considering the suitability of an existing network to CWDM and extended DWDM, a question arises: What is the magnitude of attenuation around 1383 nm? How wide is the OH- peak around this wavelength?

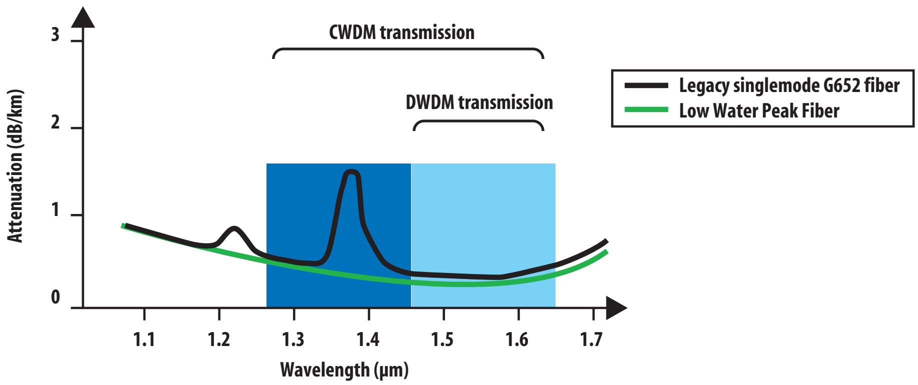
To illustrate, following are two measurements of the attenuation coefficient of fiber around 1383 nm. These sample measurements were performed on two fibers: an old one (estimated 1995) and a recent one (2000).



Fiber Attenuation Comparison

With modern fibers, the loss attributed to OH- absorption is smaller than the loss inherent to the Silica, essentially related to diffusion and which accounts for about 0.3 dB/km at 1383 nm.

The knowledge of the fiber attenuation at this 1383 nm area allows the technician to determine the compatibility with CWDM and extended DWDM transmission systems.



Fiber attenuation as a function of wavelength

Attenuation Profile (AP) Measurement Requirements

The purpose of the AP measurement is to represent the attenuation as a function of the wavelength.

Historically, this measurement was required mainly for long-haul applications. Meanwhile, with the increase of CWDM deployment and the extension of the DWDM wavelength range, it is becoming necessary to have a clear picture of the fiber attenuation other the wavelengths intended to be filled-in with traffic.

Different test methods

There are different methods of measuring the spectral attenuation:

1. Use of a broadband source and an optical spectrum analyzer (OSA). Both shall have a wavelength range equal or larger than the transmission band.
2. Use of a multi-wavelengths or tunable light source and a broadband power meter
3. Use of a multi-wavelength OTDR

In addition to the ITU-T fiber G.65x specifications, the standardization bodies provide some guidance about spectral attenuation measurements

Standards	Description	Limits
ITU-T G.692 Chapter 6.4.1	Optical interfaces for multi-channel systems with optical amplifiers	Typical 0.28 dB/km between 1530-1565 nm
TIA/EIA-455-61	Measurement of Fiber or Cable Attenuation	0.25 dB:km at 1550 nm
IEC 61300-3-7	Fiber optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-7: Examinations and measurements - Wavelength dependence of attenuation and return loss	0.25 dB/km at 1600 nm

As Attenuation Profile measurement is highly related to DWDM/CWDM installation, the use of an OSA provides the best solution in order to characterize the fiber as well as to perform the System Verification Test.

Test Procedure with JDSU solution

If C band is used for DWDM transmission, then the spectral attenuation shall be made in the C band. However, for future proof, spectral attenuation could be made at a broader wavelength range, and it would be recommended to perform the analysis, at least on the C+L band. When CWDM transmission is involved, then full band (1261 up to 1611nm) characterization must be performed.

For spectral attenuation measurement, a reference measurement is required prior to performing the measurements for test methods 1 and 2.

Using a broadband Source/OSA combination, the procedure is as follow:

1. The broadband source and the OSA have to be directly connected through a jumper. A reference measurement is then performed and saved in order to offset the jumpers' attenuation from the fiber under test.
2. The broadband source and the OSA are then connected to both ends of the fiber.
3. The attenuation measurement is be performed and subtracted from the reference to get the spectral attenuation of the fiber itself.

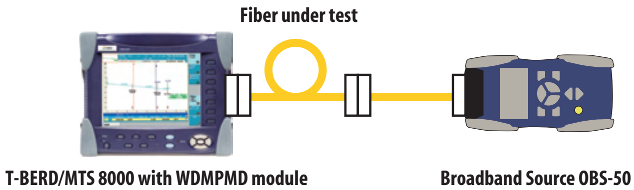
To get the attenuation profile normalized to the distance (attenuation given in dB/km), it is necessary to divide the total loss of a given wavelength by the link distance.

Spectral attenuation measurements are typically performed unidirectional.

The instrument shall have a higher dynamic range than the link itself. A 35dB dynamic range is usually enough for most of the applications, while 45dB range is required for very long distance measurements.

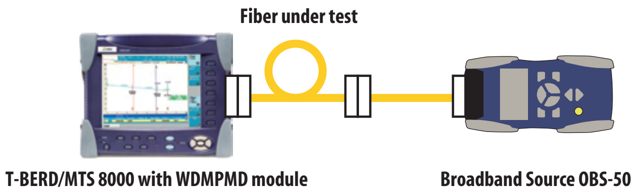
In order to cover both DWDM and CWDM applications, JDSU provides two different solutions:

– The SCL/DWDM band (1470-1625nm) solution using the Broadband handheld light source (OBS-55) combined with the MTS/T-BERD 8000 platform and the spectral attenuation plug-in module



Test setup with JDSU T-BERD/MTS 8000 and handheld broadband source

– The CWDM/Full band (1260-1640nm) solution using the Broadband light source module (E81BBS2) plugged into a T-BERD®/MTS 6000, combined with the T-BERD/MTS 8000 platform and the spectral attenuation plug-in module.



Test setup with JDSU MTS/T-BERD 8000 and full band broadband source module

Whatever the broadband source wavelength range, the JDSU T-BERD/MTS 6000 and 8000 are able to immediately provide the attenuation of the fiber of the given wavelength range.

Attenuation Profile measurement with the T-BERD/MTS 8000

Conclusion

As transmission wavelength range is getting broader and the different fiber types deployed in the field are growing more numerous, it is now becoming critical to accurately characterize the fibers intended to be used. JDSU provides innovative solutions for the field technicians to complete the job with the right performance in the right form factor.

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