

100G CWDM4 MSA

Technical Specifications

2km Optical Specifications

Participants

Editor – David Lewis, LUMENTUM
Comment Resolution Administrator – Chris Cole, Finisar

The following companies were members of the CWDM4 MSA at the release of this specification:

Company	Technical Contributors
Avago	John Petrilla
Finisar	Chris Cole, Jonathan King
LUMENTUM	David Lewis
Oclaro	Kiyohisa Hiramoto
Sumitomo Electric	Eddie Tsumura

Contacts: <http://cwdm4-msa.org>

Revisions

Rev	Date	Description
1.0	August 27, 2014	Initial Release
1.1	November 23, 2015	Replace JDSU with Lumentum. Added Section 6 on color coding.

CONTENTS

CONTENTS.....	2
TABLES.....	3
FIGURES.....	3
1 GENERAL	4
1.1 SCOPE	4
1.2 CWDM4 MODULE BLOCK DIAGRAM	4
1.3 FUNCTIONAL DESCRIPTION	5
1.4 HARDWARE SIGNALING PINS	5
1.5 MODULE MANAGEMENT INTERFACE	5
1.6 HIGH SPEED ELECTRICAL CHARACTERISTICS	5
1.7 FEC Requirements	5
1.8 MECHANICAL DIMENSIONS.....	5
1.9 OPERATING ENVIRONMENT.....	5
1.10 POWER SUPPLIES AND POWER DISSIPATION.....	5
2 CWDM4 OPTICAL SPECIFICATIONS	6
2.1 WAVELENGTH-DIVISION-MULTIPLEXED LANE ASSIGNMENTS	6
2.2 OPTICAL SPECIFICATIONS.....	6
2.2.1 CWDM4 transmitter optical specifications.....	7
2.2.2 CWDM4 receive optical specifications	8
2.2.3 CWDM4 illustrative link power budget	9
3 DEFINITION OF OPTICAL PARAMETERS AND MEASUREMENT METHODS	10
3.1 Test patterns for optical parameters	10
3.1.1 Square wave pattern definition	10
3.2 Skew and Skew Variation	10
3.3 Wavelength	10
3.4 Average optical power	10
3.5 Optical Modulation Amplitude (OMA).....	11
3.6 Transmitter and dispersion penalty (TDP)	11
3.6.1 Reference transmitter requirements.....	11
3.6.2 Channel requirements	11
3.6.3 Reference receiver requirements.....	12

CWDM4 MSA Technical Specifications Rev 1.1

3.6.4	Test procedure	12
3.7	Extinction ratio	12
3.8	Transmitter optical waveform (transmit eye).....	12
3.9	Receiver sensitivity.....	12
3.10	Stressed receiver sensitivity	13
4	FIBER OPTIC CABLING MODEL	14
5	CHARACTERISTICS OF THE FIBER OPTIC CABLING (CHANNEL)	15
5.1	Optical fiber cable	15
5.2	Optical fiber connection.....	15
5.2.1	Connection insertion loss.....	15
5.2.2	Maximum discrete reflectance	15
5.3	Medium Dependent Interface (MDI) requirements	15
6	CWDM4 Module Color Coding.....	16

TABLES

Table 2-1: Wavelength-division-multiplexed lane assignments.....	6
Table 2-2: CWDM4 operating range	6
Table 2-3: CWDM4 transmit characteristics	7
Table 2-4: CWDM4 receive characteristics	8
Table 2-5: CWDM4 illustrative power budget	9
Table 3-1: Patterns for optical parameter testing	10
Table 3-2: Transmitter compliance channel specifications	11
Table 4-1: Fiber optic cabling (channel) characteristics	14
Table 5-1: Optical fiber and cable characteristics.....	15
Table 6-1: CWDM4 Module Color Coding.....	16

FIGURES

Figure 1-1: Block diagram for CWDM4 transmit/receive paths	4
Figure 3-1 Test setup for measurement of receiver sensitivity.....	13
Figure 4-1: Fiber optic cabling model	14

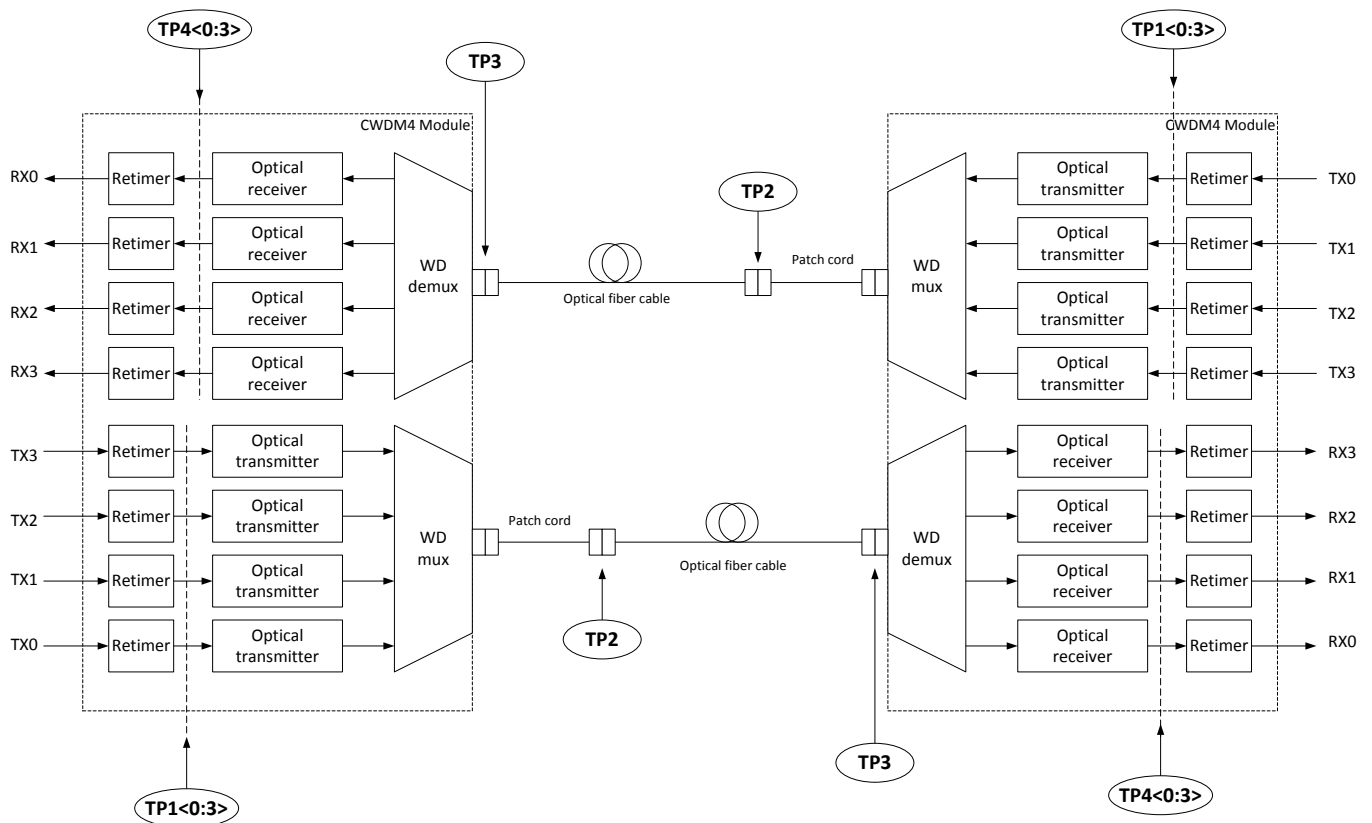
1 GENERAL

1.1 SCOPE

This Multi-Source Agreement (MSA) defines 4 x 25 Gbps Coarse Wavelength Division Multiplex (CWDM) optical interfaces for 100 Gbit/s optical transceivers for Ethernet applications including 100 GbE. Forward error correction (FEC) is required to be implemented by the host in order to ensure reliable system operation. Two transceivers communicate over single mode fibers (SMF) of length from 2 meters to at least 2 kilometers. The transceiver electrical interface is not specified by this MSA but can have, for example, four lanes in each direction with a nominal signaling rate of 25.78125 Gbps per lane.

Different form factors for the transceivers are possible. Initial implementations are expected to use either the CFP4 or the QSFP28 module form factors. Other form factors are possible and are not precluded by this MSA.

1.2 CWDM4 MODULE BLOCK DIAGRAM



WD = Wavelength division

NOTE – Specification of the retime function is beyond the scope of this MSA.

Figure 1-1: Block diagram for CWDM4 transmit/receive paths

1.3 FUNCTIONAL DESCRIPTION

CWDM4 modules comply with the requirements of this document and have the following common features: four optical transmitters; four optical receivers with signal detect; wavelength division multiplexer and demultiplexer; and a duplex optical connector for single-mode fiber. The optical connector type is vendor specific but can include SC or LC types.

1.4 HARDWARE SIGNALING PINS

Hardware signaling pins are specified in the respective module form factor MSAs.

1.5 MODULE MANAGEMENT INTERFACE

The contents of the various ID registers shall comply with the requirements of the module MSA and the respective standards. In the case of QSFP28 modules, the management interface complies with SFF-8636. For CFP4 modules, the management interface complies with the CFP MSA Management Interface Specification.

1.6 HIGH SPEED ELECTRICAL CHARACTERISTICS

The detailed high speed electrical characteristics are not defined by this MSA. 100GE modules could be implemented in compliance with IEEE 802.3bm Annex 83E, CAUI-4 chip-to-module, or OIF CEI-28G-VSR or other interfaces to be defined.

1.7 FEC REQUIREMENTS

The optical link is specified to operate at a bit error ratio (BER) of 5×10^{-5} . The host system is required to enable RS(528,514) FEC in accordance with clause 91 of IEEE-StdTM 802.3bj in order to comply with the IEEE 100G Mean Time to False Packet Acceptance (MTTFPA) requirements. The option to bypass the Clause 91 RS-FEC correction function is not supported.

1.8 MECHANICAL DIMENSIONS

Mechanical dimensions are defined in the module form factor MSA specifications. QSFP28 is defined in SFF-8661. CFP4 is defined in the CFP4 Hardware Specification.

1.9 OPERATING ENVIRONMENT

All specified minimum and maximum parameter values shall be met when the host system maintains the operating case temperature and supply voltages within the module vendor specified operating ranges. All minimum and maximum limits apply over the operating life of the system.

1.10 POWER SUPPLIES AND POWER DISSIPATION

Module vendors shall specify the module power supply requirements in accordance with the module MSA.

2 CWDM4 OPTICAL SPECIFICATIONS

2.1 WAVELENGTH-DIVISION-MULTIPLEXED LANE ASSIGNMENTS

The wavelength range for each lane of the CWDM PMD is defined in Table 2-1. The center wavelengths are spaced at 20 nm.

Table 2-1: Wavelength-division-multiplexed lane assignments

Lane	Center wavelength	Wavelength range	Module electrical lane
L ₀	1271 nm	1264.5 to 1277.5 nm	Tx0, Rx0
L ₁	1291 nm	1284.5 to 1297.5 nm	Tx1, Rx1
L ₂	1311 nm	1304.5 to 1317.5 nm	Tx2, Rx2
L ₃	1331 nm	1324.5 to 1337.5 nm	Tx3, Rx3

2.2 OPTICAL SPECIFICATIONS

The operating range for a CWDM4 PMD is defined in Table 2-2. A CWDM4 compliant PMD operates on single-mode fibers according to the specifications defined in Table 4-1 and characteristics in 5.1. A PMD that exceeds the required operating range while meeting all other optical specifications is considered compliant (e.g., operating at 2.5 km meets the operating range requirement of 2 m to 2 km).

Table 2-2: CWDM4 operating range

PMD type	Required operating range
100GE-CWDM4	2 m to 2 km

2.2.1 CWDM4 transmitter optical specifications

The CWDM4 transmitter shall meet the specifications defined in Table 2-3.

Table 2-3: CWDM4 transmit characteristics

Description	Value	Unit
Signaling rate, each lane (range) 100GE	25.78125 ± 100 ppm	GBd
Line wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	8.5	dBm
Average launch power, each lane (max)	2.5	dBm
Average launch power, each lane ^a (min)	-6.5	dBm
Optical Modulation Amplitude (OMA), each lane (max)	2.5	dBm
Optical Modulation Amplitude (OMA), each lane (min) ^b	-4.0	dBm
Launch power in OMA minus TDP, each lane (min)	-5.0	dBm
Transmitter and dispersion penalty (TDP), each lane (max) ^d	3.0	dB
Average launch power of OFF transmitter, each lane (max)	-30	dBm
Extinction ratio (min)	3.5	dB
Optical return loss tolerance (max)	20	dB
Transmitter reflectance ^c (max)	-12	dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}	

^aAverage launch power, each lane (min) is informative and not the principal indicator of signal strength. A transmitter with launch power below this value cannot be compliant; however, a value above this does not ensure compliance.

^bEven if the TDP < 1.0dB, the OMA (min) must exceed this value.

^cTransmitter reflectance is defined looking into the transmitter.

^dTDP does not include a penalty for multi-path interference (MPI).

2.2.2 CWDM4 receive optical specifications

The CWDM4 receiver shall meet the specifications defined in Table 2-4.

Table 2-4: CWDM4 receive characteristics

Description	Value	Unit
Signaling rate, each lane (range) 100GE	25.78125 ± 100 ppm	GBd
Line wavelengths (range)	1264.5 to 1277.5 1284.5 to 1297.5 1304.5 to 1317.5 1324.5 to 1337.5	nm
Damage threshold, each lane (min) ^a	3.5	dBm
Average receive power, each lane (max)	2.5	dBm
Average receive power, each lane ^b (min)	-11.5	dBm
Receive power, each lane (OMA) (max)	2.5	dBm
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA), each lane (max) at 5 x 10 ⁻⁵ BER ^c	-10.0	dBm
Stressed receiver sensitivity (OMA), each lane ^d (max)	-7.3	dBm
Conditions of stressed receiver sensitivity test:		
Vertical eye closure penalty, ^e each lane	1.9	dB
Stressed eye J2 Jitter, ^e each lane	0.33	UI
Stressed eye J4 Jitter, ^e each lane	0.48	UI
SRS eye mask definition ^e { X1, X2, X3, Y1, Y2, Y3}	{0.39, 0.5, 0.5, 0.39, 0.39, 0.4}	

^aThe receiver shall be able to tolerate, without damage, continuous exposure to an optical signal having this average power level

^bAverage receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.

^cReceiver sensitivity (OMA), each lane (max) at 5 x 10⁻⁵ BER is a normative specification.

^dMeasured with conformance test signal at TP3 (see 3.10) for BER = 5x10⁻⁵.

^eVertical eye closure penalty, stressed eye J2 Jitter, stressed eye J4 Jitter, and SRS eye mask definition are test conditions for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

2.2.3 CWDM4 illustrative link power budget

An illustrative power budget and penalties for CWDM4 are shown in Table 2-5.

Table 2-5: CWDM4 illustrative power budget

Description	Value	Unit
Power budget (for max TDP)	8.0	dB
Operating distance	2.0	km
Channel insertion loss ^a	5.0	dB
Maximum discrete reflectance	-26	dB
Allocation for penalties (for max TDP)	3.0	dB
Additional insertion loss allowed	0	dB

^aThe channel insertion loss budget may include up to 1 dB MPI loss penalty with worst case transmitter and worst case connector MPI.

3 DEFINITION OF OPTICAL PARAMETERS AND MEASUREMENT METHODS

All optical measurements shall be made through a short patch cable, between 2 m and 5 m in length, unless otherwise specified.

3.1 TEST PATTERNS FOR OPTICAL PARAMETERS

Table 3-1: Patterns for optical parameter testing

Parameter	Pattern	Sub-clause ^a
Wavelength	PRBS31	3.3
Side mode suppression ratio	PRBS31	--
Average optical power	PRBS31	3.4
Optical modulation amplitude (OMA)	Square wave	3.5
Transmitter and dispersion penalty (TDP)	PRBS31	3.6
Extinction ratio	PRBS31	3.7
Transmitter optical waveform	PRBS31	3.8
Stressed receiver sensitivity	PRBS31	3.10
Calibration of OMA for receiver tests	PRBS9	3.10
Vertical eye closure penalty calibration	PRBS31	3.10

^aThese sub-clauses make reference to relevant clauses of IEEE Std 802.3™-2012.

Note that the PRBS pattern generator and pattern checker are defined in IEEE Std 802.3™-2012 clauses 49.2.9 and 49.2.12 respectively.

3.1.1 Square wave pattern definition

A pattern consisting of eight ones followed by an equal run of zeroes may be used as a square wave.

3.2 SKEW AND SKEW VARIATION

Refer to IEEE Std 802.3™-2012 Clause 87.8.2. CWDM4 MSA transceivers shall comply with the skew and skew variation limits of clause 88.3.2.

3.3 WAVELENGTH

Measure per TIA/EIA-455-127-A or IEC 61280-1-3.

3.4 AVERAGE OPTICAL POWER

Measure using the methods given in IEC 61280-1-1 with all channels not being measured turned off.

3.5 OPTICAL MODULATION AMPLITUDE (OMA)

Refer to IEEE Std 802.3-2012 Clause 52.9.5. OMA is measured with a square wave (8 ones, 8 zeros) test pattern. Each lane may be tested individually with all other lanes turned off, or by using an optical filter as defined in 3.6 if the other lanes are active.

3.6 TRANSMITTER AND DISPERSION PENALTY (TDP)

TDP shall be as defined in IEEE Std 802.3-2012 Clause 52.9.10 with the exception that each optical lane is tested individually using an optical filter to separate the lane under test from the others.

The optical filter pass band ripple shall be limited to 0.5 dB peak-to-peak and the isolation is chosen such that the ratio of the power in the lane being measured to the sum of the powers of all the other lanes is greater than 20 dB (see ITU-T G.959.1 Annex B). The lanes not under test shall be operating with PRBS31 bit streams.

3.6.1 Reference transmitter requirements

Refer to IEEE Std 802.3-2012 Cl. 88.8.5.1.

3.6.2 Channel requirements

The transmitter is tested using an optical channel that meets the requirements listed in Table 3-2.

Table 3-2: Transmitter compliance channel specifications

Type	Dispersion ^a (ps/nm)		Insertion loss ^b	Optical return loss ^c
	Minimum	Maximum		
CWDM4	$0.0465 * \lambda * [1 - (1324/\lambda)^4]$	$0.0465 * \lambda * [1 - (1300/\lambda)^4]$	Minimum	20 dB

^a The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 2 km for CWDM4.

^b There is no intent to stress the sensitivity of the BERT's optical receiver.

^c The optical return loss is applied at TP2, i.e. after a 2 meter patch cord.

A transmitter is to be compliant with a total dispersion at least as negative as the “minimum dispersion” and at least as positive as the “maximum dispersion” columns specified in Table 3-2 for the wavelength of the device under test. This may be achieved with channels consisting of fibers with lengths chosen to meet the dispersion requirements.

To verify that the fiber has the correct amount of dispersion, the measurement method defined in IEC 60793-1-42 may be used. The measurement is made in the linear power regime of the fiber.

The channel provides an optical return loss specified in Table 3-2. The state of polarization of the back reflection is adjusted to create the greatest RIN.

3.6.3 Reference receiver requirements

Refer to IEEE Std 802.3-2012 Cl. 88.8.5.3.

3.6.4 Test procedure

The test procedure is as defined in IEEE Std 802.3-2012 Cl. 52.9.10.4 with the exception that all lanes are operational in both directions (transmit and receive), each lane is tested individually using an optical filter to separate the lane under test from the others, and the BER of 5×10^{-5} is for the lane under test on its own.

3.7 *EXTINCTION RATIO*

Extinction ratio is measured using the methods specified in IEC 61280-2-2, with the lanes not under test turned off.

3.8 *TRANSMITTER OPTICAL WAVEFORM (TRANSMIT EYE)*

Refer to IEEE Std 802.3-2012 Cl. 88.8.8.

3.9 *RECEIVER SENSITIVITY*

The nominal sensitivity of each receiver lane, is measured in OMA using the setup of Figure 3-1. The sensitivity must be corrected for any significant reference transmitter impairments including any vertical eye closure. It should be measured at the eye center or corrected for off-center sampling. The reference transmitter wavelength(s) shall comply with the ranges in Table 2-4.

The reference transmitter is a high-quality instrument grade device, which can be implemented by a CW laser modulated by a high-performance modulator. It should have the following basic requirements:

- a) The rise/fall times should be less than 12 ps at 20% to 80%.
- b) The output optical eye is symmetric and passes the transmitter optical waveform test of 3.8.
- c) In the center 20% region of the eye, the worst-case vertical eye closure penalty as defined in 802.3-2012 87.8.11.2 is less than 0.5 dB.
- d) Total jitter less than 0.2 UI peak-to-peak
- e) RIN of less than -138 dB/Hz.

Center of the eye is defined as the time halfway between the left and right sampling points within the eye where the measured BER is greater than or equal to 1×10^{-3} .

The clock recovery unit (CRU) used in the sensitivity measurement has a corner frequency of less than or equal to 10 MHz and a slope of 20 dB/decade. When using a clock recovery unit as

a clock for BER measurement, passing of low frequency jitter from the data to the clock removes this low-frequency jitter from the measurement.

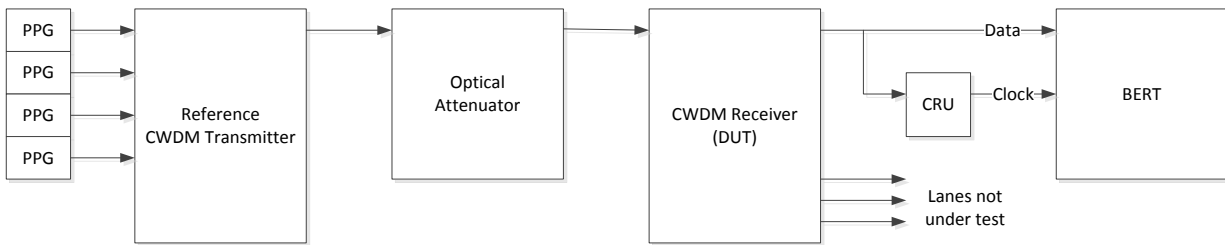


Figure 3-1 Test setup for measurement of receiver sensitivity

3.10 STRESSED RECEIVER SENSITIVITY

Refer to IEEE Std 802.3-2012 Cl. 88.8.10. Note that for CWDM4 transceivers J9 is replaced by J4 and also that the test BER is 5×10^{-5} instead of 1×10^{-12} . J4 jitter is defined in IEEE 802.3bm Cl. 95.8.8.4. Each lane is tested individually with all other Rx and Tx channels turned ON and receiving or transmitting PRBS31 signals. The maximum OMA difference between the Rx lane under test and the other Rx lanes not under test is 4.5 dB.

The Gaussian noise generator, the amplitude of the sinusoidal interferers, and the low-pass filter are adjusted so that the VECP, stressed eye J2 Jitter, and stressed eye J4 Jitter specifications given in Table 2-4 are met simultaneously while also passing the stressed receiver eye mask in Table 2-4 according to the methods in 802.3-2012 clause 88.8.8 (the random noise effects such as RIN, or random clock jitter, do not need to be minimized).

4 FIBER OPTIC CABLING MODEL

The fiber optic cabling model is shown in Figure 4-1.

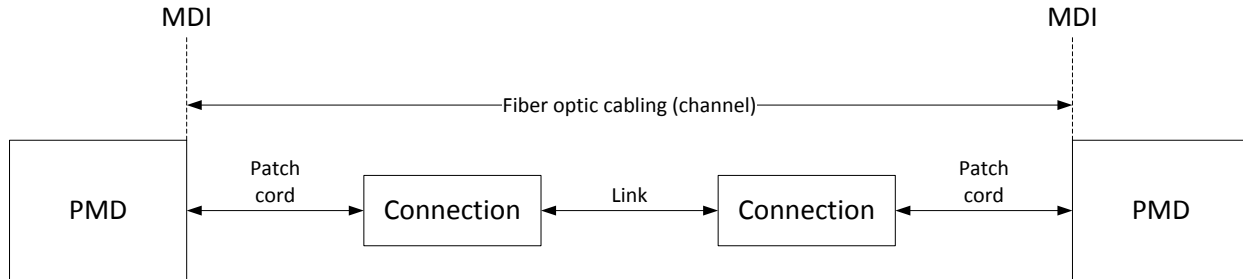


Figure 4-1: Fiber optic cabling model

The channel insertion loss is given in Table 4-1. A channel may contain additional connectors as long as the optical characteristics of the channel, such as attenuation, dispersion, reflections and polarization mode dispersion meet the specifications. Insertion loss measurements of installed fiber cables are made in accordance with IEC 61280-4-2 using the one-cord reference method. The fiber optic cabling model (channel) defined here is the same as a simplex fiber optic link segment. The term channel is used here for consistency with generic cabling standards.

Table 4-1: Fiber optic cabling (channel) characteristics

Description	CWDM4	Unit
Operating distance (max)	2	km
Channel insertion loss ^{a,b} (max)	5	dB
Channel insertion loss (min)	0	dB
Positive dispersion ^b (max)	6.7	ps/nm
Negative dispersion ^b (min)	-11.9	ps/nm
DGD_max ^c	3.0	ps
Optical return loss (min)	21	dB

a) These channel loss values include cable, connectors and splices.

b) Over the wavelength range 1264.5 to 1337.5 nm.

c) Differential Group Delay (DGD) is the time difference at reception between the fractions of a pulse that were transmitted in the two principal states of polarization of an optical signal. DGD_max is the maximum differential group delay that the system must tolerate.

5 CHARACTERISTICS OF THE FIBER OPTIC CABLING (CHANNEL)

The CWDM4 fiber optic cabling shall meet the specifications defined in Table 4-1. The fiber optic cabling consists of one or more sections of fiber optic cable and any intermediate connections required to connect sections together.

5.1 OPTICAL FIBER CABLE

The fiber optic cable requirements are satisfied by cables containing IEC 60793-2-50 type B1.1 (dispersion un-shifted single-mode), type B1.3 (low water peak single-mode), or type B6_a (bend insensitive) fibers and the requirements in Table 5-1 where they differ.

Table 5-1: Optical fiber and cable characteristics

Description	Value	Unit
Nominal fiber specification wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.5 ^a	dB/km
Zero dispersion wavelength (λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope (max) (S_0)	0.093	ps/nm ² km

^aThe 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3.

5.2 OPTICAL FIBER CONNECTION

An optical fiber connection, as shown in Figure 4-1, consists of a mated pair of optical connectors.

5.2.1 Connection insertion loss

The maximum link distances for single-mode fiber are calculated based on an allocation of 3.89 dB total connection and splice loss. For example, this allocation supports seven connections with an average insertion loss per connection of 0.5 dB. Connections with different loss characteristics may be used provided the requirements of Table 4-1 are met.

5.2.2 Maximum discrete reflectance

The maximum discrete reflectance shall be less than -26 dB.

5.3 MEDIUM DEPENDENT INTERFACE (MDI) REQUIREMENTS

The PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the “fiber optic cabling” (as shown in Figure 4-1). Examples of an MDI include the following:

- a) Connectorized fiber pigtail
- b) PMD receptacle

When the MDI is a connector plug and receptacle connection, it shall meet the interface performance specifications of IEC 61753-1-1 and IEC 61753-021-2.

NOTE---Transmitter compliance testing is performed at TP2 i.e. after a 2 meter patch cord, not at the MDI.

6 CWDM4 Module Color Coding

Transceiver modules compliant to the CWDM4 MSA Specifications use a color code to indicate the application. This color code can be on a module bail latch, pull tab, or other visible feature of the module when installed in a system. The color code scheme is specified in Table 6-1.

Table 6-1: CWDM4 Module Color Coding

Color Code	Application
Green	100 Gb/s CWDM4 2 km reach