

100G 4WDM-20 & 4WDM-40 MSA Technical Specifications

20km and 40km Optical Specifications Release 1.0

(4-Wavelength WDM MSA)

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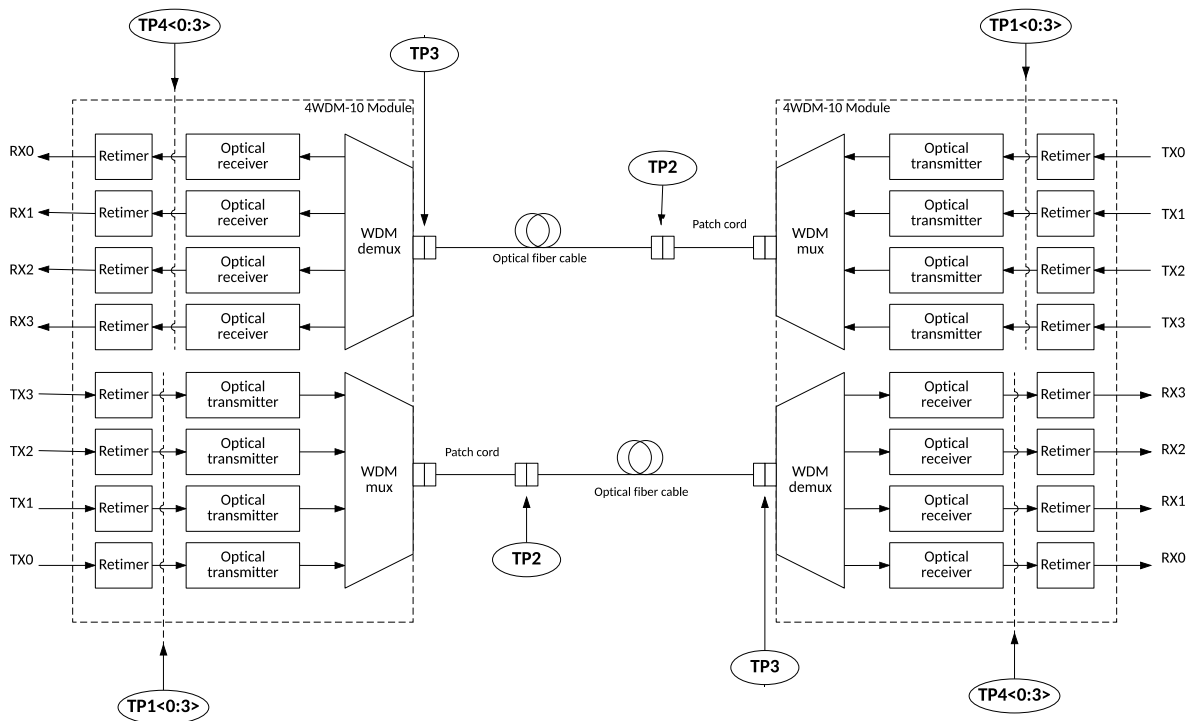
1 GENERAL

1.1 SCOPE

This specification defines 4 x 25 Gbps Local Area Network Wavelength Division Multiplex (LAN-WDM) optical interfaces for 100 Gbps optical transceivers for Ethernet applications including 100 GbE. Forward error correction (FEC) is a link requirement in order to ensure reliable system operation. Two transceivers communicate over single mode fibers (SMF) of length from 2 meters to at least 20 or 40 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. The QSFP28 module is expected to be a popular form factor for these applications. Other form factors are possible and are not precluded by this MSA.

1.2 4WDM-20 & 4WDM-40 MODULE BLOCK DIAGRAM



WDM = Wavelength division multiplexing

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

Figure 1-1: Block diagram for 4WDM-20 and 4WDM-40 transmit/receive paths

1.3 FUNCTIONAL DESCRIPTION

The 4WDM-20 and 4WDM-40 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 CONTACTS

Hardware signaling contacts 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. In the case of μ QSFP modules, the management interface complies with μ QSFP specifications.

1.6 HIGH SPEED ELECTRICAL CHARACTERISTICS

The detailed high speed electrical characteristics are not defined by this specification. The 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} . RS(528,514) FEC in accordance with clause 91 of IEEE-Std 802.3TM-2015 is assumed to meet IEEE 100G Mean Time to False Packet Acceptance (MTTFPA) requirement. FEC can be implemented on the host as depicted in the IEEE figure below. Other implementations are possible.

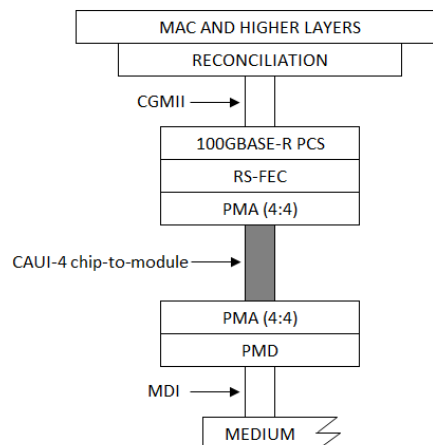


Figure 1-2: Example FEC implemented with PMD

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 4WDM-20 and 4WDM-40 OPTICAL SPECIFICATIONS

2.1 WAVELENGTH-DIVISION-MULTIPLEXED LANE ASSIGNMENTS

The wavelength range for each lane of the 4WDM-20 and 4WDM-40 PMD (physical medium dependent sublayer) is defined in Table 2-1. The center wavelengths are spaced by 4.5 nm.

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

| Lane | Center wavelength | Wavelength range |
|----------------|-------------------|-----------------------|
| L ₀ | 1295.56 nm | 1294.53 to 1296.59 nm |
| L ₁ | 1300.05 nm | 1299.02 to 1301.09 nm |
| L ₂ | 1304.58 nm | 1303.54 to 1305.63 nm |
| L ₃ | 1309.14 nm | 1308.09 to 1310.19 nm |

2.2 OPTICAL SPECIFICATIONS

The operating range for a 4WDM-20 and 4WDM-40 PMD is defined in

Table 2-2. A 4WDM-20 and 4WDM-40 compliant PMD operates on single-mode fibers according to the specifications defined in Table 4-1 and characteristics in Table 5-1. A PMD that exceeds the required operating range while meeting all other optical specifications is considered compliant (e.g., operating at 40.5 km meets the operating range requirement of 2 m to 40 km of 4WDM-40).

Table 2-2: 4WDM-20 and 4WDM-40 operating range

| PMD type | Required operating range |
|---------------|--------------------------|
| 100GE-4WDM-20 | 2 m to 20 km |
| 100GE-4WDM-40 | 2 m to 40 km |

The bit error ratio (BER) shall be less than 5×10^{-5} . Refer to section 95.1.1 Bit error ratio of IEEE Std 802.3™-2015.

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2.2.1 4WDM-20 and 4WDM-40 transmitter optical specifications

The 4WDM-20 and 4WDM-40 transmitter shall meet the specifications defined in Table 2-3.

Table 2-3: 4WDM-20 and 4WDM-40 transmit characteristics

| Description | 4WDM-20 | 4WDM-40 | Unit |
|--|--|---------|------|
| Signaling rate, each lane (range) 100GE | 25.78125 ± 100 ppm | | GBd |
| Line wavelengths (range) | 1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19 | | nm |
| Side-mode suppression ratio (SMSR), (min) | 30 | | dB |
| Total average launch power (max) | 10.5 | 12.5 | dBm |
| Average launch power, each lane (max) | 4.5 | 6.5 | dBm |
| Average launch power, each lane ^a (min) | -4.3 | -2.5 | dBm |
| Optical Modulation Amplitude (OMA), each lane (max) | 4.5 | 6.5 | dBm |
| Optical Modulation Amplitude (OMA), each lane (min) ^b | -1.3 | 0.5 | dBm |
| Launch power in OMA minus TDP, each lane (min) | -2.3 | -0.5 | dBm |
| Difference in launch power between any two lanes (Average and OMA) (max) | 5.0 | 4.0 | dB |
| Transmitter and dispersion penalty (TDP), each lane (max) ^d | 2.8 | 3.0 | dB |
| Average launch power of OFF transmitter, each lane (max) | -30 | | dBm |
| Extinction ratio (min) | 4.0 | 4.5 | dB |
| Optical return loss tolerance (min) | 20 | | dB |
| Transmitter reflectance ^c (max) | -26 | | dB |
| Transmitter eye mask definition ^e {X1, X2, X3, Y1, Y2, Y3} | {0.25, 0.4, 0.45, 0.25, 0.28, 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).

^eEye mask hit ratio is 5E-5.

2.2.2 4WDM-20 and 4WDM-40 receive optical specifications

The 4WDM-20 and 4WDM-40 receiver shall meet the specifications defined in Table 2-4.

Table 2-4: 4WDM-10 receive characteristics

| Description | 4WDM-20 | 4WDM-40 | Unit |
|--|--|---------|------|
| Signaling rate, each lane (range) 100GE | 25.78125 ± 100 ppm | | GBd |
| Line wavelengths (range) | 1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19 | | nm |
| Damage threshold, each lane (min) ^a | 5.5 | -2.5 | dBm |
| Average receive power, each lane (max) | 4.5 | -3.5 | dBm |
| Average receive power, each lane ^b (min) | -14.5 | -20.5 | dBm |
| Receive power, each lane (OMA) (max) | 4.5 | -3.5 | dBm |
| Receiver reflectance (max) | -26 | | dB |
| Receiver sensitivity (OMA), each lane (max) at 5 x 10 ⁻⁵ BER ^c | -12.5 | -18.5 | dBm |
| Stressed receiver sensitivity (OMA), each lane ^d (max) | -10.0 | -16.0 | dBm |
| Conditions of stressed receiver sensitivity test: | | | |
| Vertical eye closure penalty, ^e each lane | 2.5 | | 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 4WDM-20 and 4WDM-40 illustrative link power budget overview

An illustrative power budget and penalties for 4WDM-20 and 4WDM-40 are shown in Table 2-5.

Table 2-5: 4WDM-20 and 4WDM-40 illustrative power budget

| Description | 4WDM-20 | 4WDM-40 | Unit |
|--|-----------|----------|------|
| Power budget (for max TDP) | 13.0 | 21.0 | dB |
| Operating distance | 20 | 40 | km |
| Channel insertion loss ^a | 0 to 10.2 | 10 to 18 | dB |
| Maximum discrete reflectance | -26 | -26 | dB |
| Allocation for penalties (for max TDP) | 2.8 | 3.0 | dB |
| Additional insertion loss allowed | 0 | 0 | dB |

^aThe channel insertion loss budget may include up to 0.2 dB MPI loss penalty to support worst case transmitter/receiver with worst case connector.

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 of this specification make reference to relevant clauses of IEEE Std 802.3™-2015.

Note that the PRBS pattern generator and pattern checker are defined in IEEE Std 802.3™-2015 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™-2015 Clause 87.8.2. 4WDM-10 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™-2015 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™-2015 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™-2015 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 | | |
| 4WDM-20 | $0.465 * \lambda * [1 - (1324/\lambda)^4]$ | $0.465 * \lambda * [1 - (1300/\lambda)^4]$ | Minimum | 20 dB |
| 4WDM-40 | $0.93 * \lambda * [1 - (1324/\lambda)^4]$ | $0.93 * \lambda * [1 - (1300/\lambda)^4]$ | Minimum | 20 dB |

^a The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 20 km for 4WDM-20 and 40km for 4WDM-40.

^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™-2015 Cl. 88.8.5.3.

3.6.4 Test procedure

The test procedure is as defined in IEEE Std 802.3™-2015 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™-2015 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 11 ps at 20% to 80%.
- b) The output optical eye is symmetric and passes the transmitter optical waveform test of sub-clause 3.8.
- c) In the center 20% region of the eye, the worst-case vertical eye closure penalty as defined in IEEE 802.3™-2015 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.

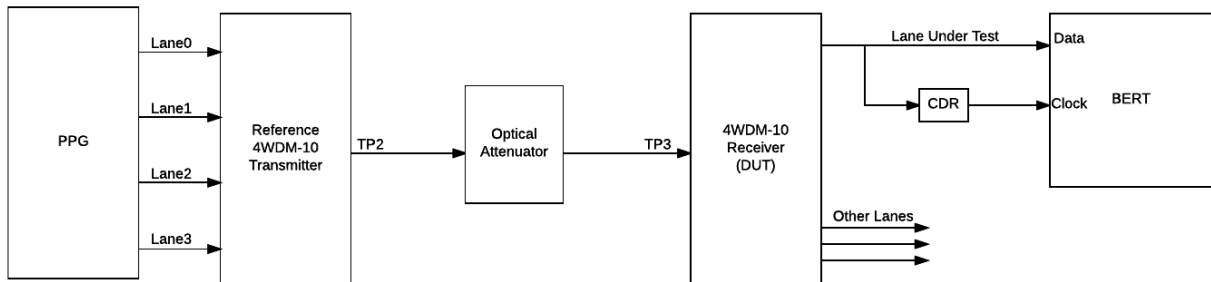


Figure 3-1: Test setup for measurement of receiver sensitivity

3.10 STRESSED RECEIVER SENSITIVITY

Refer to IEEE Std 802.3™-2015 Cl. 88.8.10. Note that for 4WDM-20 and 4WDM-40 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 Std 802.3™-2015 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 5.5 dB for 4WDM-20 and 4.5dB for 4WDM-40.

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 IEEE 802.3™-2015 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.

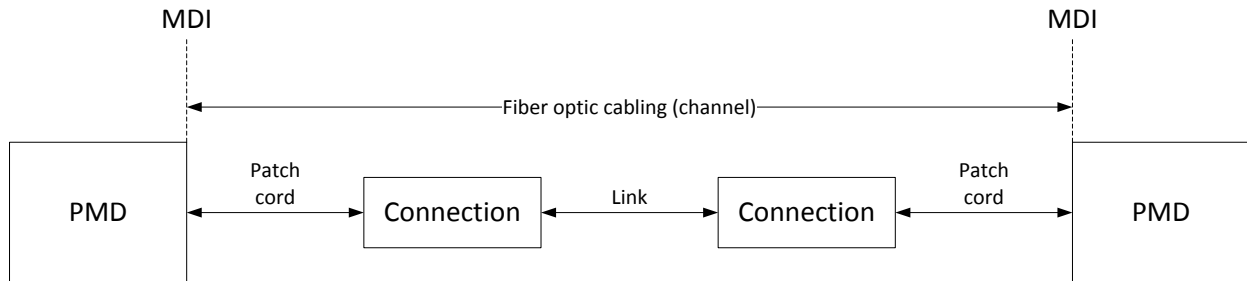


Figure 4-1: Fiber optic cabling model

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 | 4WDM-20 | 4WDM-40 | Unit |
|---|---------|---------|-------|
| Operating distance (max) | 20 | 40 | km |
| Channel insertion loss ^{a,b} (max) | 10.2 | 18 | dB |
| Channel insertion loss (min) | 0 | 10 | dB |
| Positive dispersion ^b (max) | 19 | 36 | ps/nm |
| Negative dispersion ^b (min) | -57 | -114 | ps/nm |
| DGD_max ^c | 8.4 | 10.3 | ps |
| Optical return loss (min) | 21 | 21 | dB |

^aThese channel loss values include optical cable, connectors and splices, with up to 0.2 dB allocation for MPI penalty.

^bOver the wavelength range 1294.53 to 1310.19 nm.

^cDifferential 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 4WDM-20 and 4WDM-40 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) | 0.43 ^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 |

^a Links longer than 30 km for the same link power budget are considered engineered links. Attenuation for such links needs to be less than the worst case specified in this table.

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 the 4WDM-20 and 4WDM-40 single-mode fiber are calculated based on an allocation of 1.6 dB total for connections and splice loss. The cable plant is required to control MPI such that the penalty is ≤ 0.2 dB. For example, this allocation supports either up to two connectors with ≤ -26 dB reflectance and up to 8 splices of ≤ -55 dB reflectance, or up to six connectors with ≤ -35 dB reflectance and up to 6 splices ≤ -55 dB reflectance. Connections with different loss characteristics may be used provided the requirements of Table 4-1 are met.

5.2.2 Maximum discrete reflectance and example cable plants

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 4WDM-20 and 4WDM-40 Module Color Coding

Transceiver modules compliant to the 4WDM-20 and 4WDM-40 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: 4WDM-20 and 4WDM-40 Module Color Coding

| Color Code | Application |
|-------------------------|------------------------------|
| Brown Pantone 478U | 100 Gbps 4WDM-20 20 km reach |
| Tangerine Pantone 1575U | 100 Gbps 4WDM-40 40 km reach |