100G-FR and 100G-LR Technical Specifications

100G Lambda MSA

Rev 1.0 January 9, 2018

Chair – Mark Nowell, Cisco Systems

Co-Chair - Jeffery J. Maki, Juniper Networks

Marketing Chair - Rang-Chen (Ryan) Yu, Molex

Editor – Tom Palkert, Macom/Molex

The following companies were members of the 100G Lambda MSA at the release of this specification:

Company	Technical Contributors
Alibaba	
Applied Optoelectronics	
Arista	
Broadcom	
Ciena	
Cisco	
Finisar	
FIT	
Inphi	
Intel	
Juniper Networks	
Lumentum	
Luxtera	
Macom	
MaxLinear	
Microsoft	
Molex	

NeoPhotonics	
Nokia	
Oclaro	
Sumitomo Electric	
Semtech	
Source Photonics	

Revisions

Rev	Date	Description
1.0		Initial Release

CONTENTS

CONTENTS....2
TABLES....3
FIGURES....3
1 GENERAL....4
1.1 SCOPE....4
1.2 100G-FR and 100G-LR MODULE BLOCK DIAGRAM....4
1.3 FUNCTIONAL DESCRIPTION....4
1.4 HARDWARE SIGNALING PINS....5
1.5 MODULE MANAGEMENT INTERFACE....5
1.6 FEC Requirements....5
1.7 HIGH SPEED ELECTRICAL CHARACTERISTICS....5
1.8 MECHANICAL DIMENSIONS....5
2 100G-FR and 100G-LR OPTICAL SPECIFICATIONS....6
2.1 OPTICAL SPECIFICATIONS....6
2.1.1 100G-FR and 100G-LR transmitter optical specifications....7
2.1.2 100G-FR and 100G-LR receive optical specifications....8
2.1.3 100G-FR and 100G-LR illustrative link power budget....9
3 DEFINITION OF OPTICAL PARAMETERS AND MEASUREMENT METHODS....11
3.1 Test patterns for optical parameters....11
3.2 Skew and Skew Variation....12
3.3 Wavelength....12

3.4 Average optical power 12
3.5 Optical Modulation Amplitude (OMA) 12
3.6 Transmitter and dispersion Eye Closure penalty (TDECQ) 12
3.6.1 Channel requirements 12
3.6.2 Reference receiver requirements 13
3.7 Extinction ratio 13
3.8 Relative intensity noise (RIN) 13
3.9 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 100G-FR and 100G-LR Module Color Coding 16

TABLES

Table 2-1: 100G-FR and 100G-LR operating range 6
Table 2-2: 100G-FR and 100G-LR transmit characteristics 7
Table 2-3: 100G-FR and 100G-LR receive characteristics 8
Table 2-4: 100G-FR and 100G-LR illustrative power budget (ER > 4.5 dB) 9
Table 2-5: 100G-FR and 100G-LR Maximum value for each discrete reflectance 10
Table 3-1: Patterns for optical parameter testing 11
Table 3-2: Patterns for optical parameter testing 11
Table 3-3: Transmitter compliance channel specifications 12
Table 4-1: Fiber optic cabling (channel) characteristics 14
Table 5-1: Optical fiber and cable characteristics 15
Table 6-1: 100G-FR and 100G-LR Module Color Coding 16

FIGURES

Figure 1-1: Block diagram for 100G-FR and 100G-LR transmit/receive paths 4
Figure 2-1: Stressed receiver sensitivity mask for 100G-FR and LR 9
Figure 4-1: Fiber optic cabling model 14

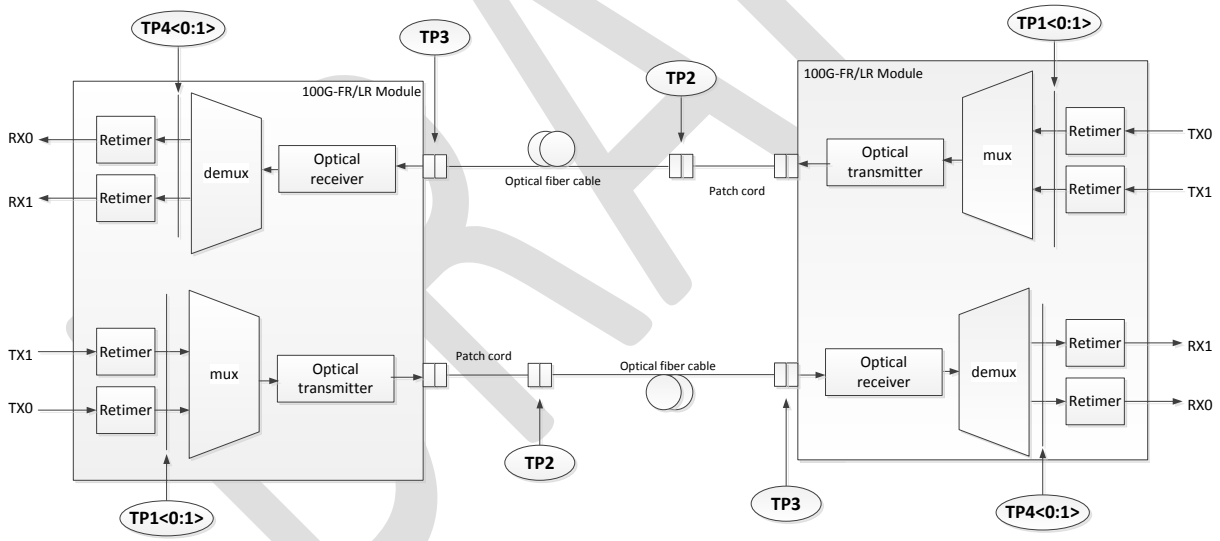
1 GENERAL

1.1 SCOPE

This Multi-Source Agreement (MSA) defines single lane 100 Gbps 2km and 10km optical interface for 100 Gbps optical transceivers for Ethernet applications. 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 using the 100G-FR specification and 2 meters to at least 10 kilometers using the 100G-LR specification. 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 26.5625 Gbps, two lanes in each direction with a nominal signaling rate of 53.125 Gbps per lane or a single lane in each direction with a nominal signaling rate of 106 .25 Gbps per lane.

A variety of form factors for the 100G-FR and LR transceivers are possible and none are precluded by this MSA.

1.2 100G-FR AND 100G-LR MODULE BLOCK DIAGRAM



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

Figure 1-1: Block diagram for 100G-FR and 100G-LR transmit/receive paths

1.3 FUNCTIONAL DESCRIPTION

100G-FR and 100G-LR modules comply with the requirements of this document and have the following common features: one optical transmitter; one optical receiver with signal detect and a duplex optical connector for single-mode fiber. The optical connector type is vendor specific but can include SC, LC, MPO or CS 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.

1.6 FEC REQUIREMENTS

The system is required to enable FEC in accordance with clause 121.1.1 of IEEE-Std 802.3bs™. The option to bypass the FEC correction function is not supported.

1.7 HIGH SPEED ELECTRICAL CHARACTERISTICS

The detailed high speed electrical characteristics are not defined by this MSA. 100GE modules could be implemented in compliance with applicable electrical interface specifications.

1.8 MECHANICAL DIMENSIONS

Mechanical dimensions are defined in module form factor MSA specifications.

2 100G-FR and 100G-LR OPTICAL SPECIFICATIONS

2.1 OPTICAL SPECIFICATIONS

The operating range for the 100G-FR and 100G-LR PMDs are defined in Table 2-1. A 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 2.5 km meets the operating range requirement of 2 m to 2 km).

Table 2-1: 100G-FR and 100G-LR operating range

PMD type	Required operating range
100G-FR	2 m to 2 km
100G-LR	2 m to 10 km

2.1.1 100G-FR and 100G-LR transmitter optical specifications

The 100G-FR and 100G-LR transmitters shall meet the specifications defined in Table 2-2.

Table 2-2: 100G-FR and 100G-LR transmit characteristics

Description	100G-FR Value	100G-LR Value	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1304.5- 1317.5	1304.5- 1317.5	nm
Side-mode suppression ratio (SMSR), (min)	30	30	dB
Average launch power, (max)	4	4.5	dBm
Average launch power, [a] (min)	-2.4	-1.4	dBm
Outer Optical Modulation Amplitude (OMAouter), each lane (max)	4.2	4.7	dBm
Outer Optical Modulation Amplitude (OMAouter), each lane[b] (min)	-0.2	0.7	dBm
Launch power in OMAouter minus TDECQ, each lane (min) ER≥4.5dB[b]	-1.6	-0.7	dBm
Launch power in OMAouter minus TDECQ, each lane (min) ER<4.5dB	-1.5	-0.6	dBm
Transmitter and dispersion penalty Eye Closure for PAM4 (TDECQ), (max)	3.4	3.4	dB
Average launch power of OFF transmitter, (max)	-15	-15	dBm
Extinction ratio (min)	3.5	3.5	dB
Optical return loss tolerance (max)	17.1	15.6	dB
Transmitter reflectance[c] (max)	-26	-26	dB
$RIN_{17.1}$ OMA (max) for FR, $RIN_{15.6}$ OMA (max) for LR	-136	-136	dB/Hz
[a]Average 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.			
[b] Even if the TDECQ < 1.4 dB for an extinction ratio of ≥ 4.5 dB or TDECQ < 1.3 dB for an extinction ratio of < 4.5 dB, the OMAouter (min) must exceed this value.			
[c]Transmitter reflectance is defined looking into the transmitter.			

2.1.2 100G-FR and 100G-LR receive optical specifications

The 100G-FR and 100G-LR receiver shall meet the specifications defined in Table 2-3.

Table 2-3: 100G-FR and 100G-LR receive characteristics

Description	100G-FR Value	100G-LR Value	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1304.5 to 1317.5	1304.5 to 1317.5	Nm
Damage threshold, each lane (min)[a]	5.5	5.5	dBm
Average receive power, each lane (max)	4.5	4.5	dBm
Average receive power, each lane[b] (min)	-6.4	-7.7	dBm
Receive power, each lane (OMAouter) (max)	4.7	4.7	dBm
Receiver reflectance (max)	-26	-26	dB
Stressed receiver sensitivity (OMAouter), each lane[c] (max)	See Figure 2-1		dBm
Conditions of stressed receiver sensitivity test:			
Stressed eye closure for PAM4 (SECQ), lane under test	0.9 to 3.4	0.9 to 3.4	dB

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical signal having this average power level

[b]Average 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.

[c]Measured with conformance test signal at TP3 (see 3.10) for BER = 2.4×10^{-4}. A compliant receiver shall have stressed receiver sensitivity (OMA outer), each lane values below the mask of Figure 2-1, for SECQ values between 0.9 and 3.4 dB. See 3.10

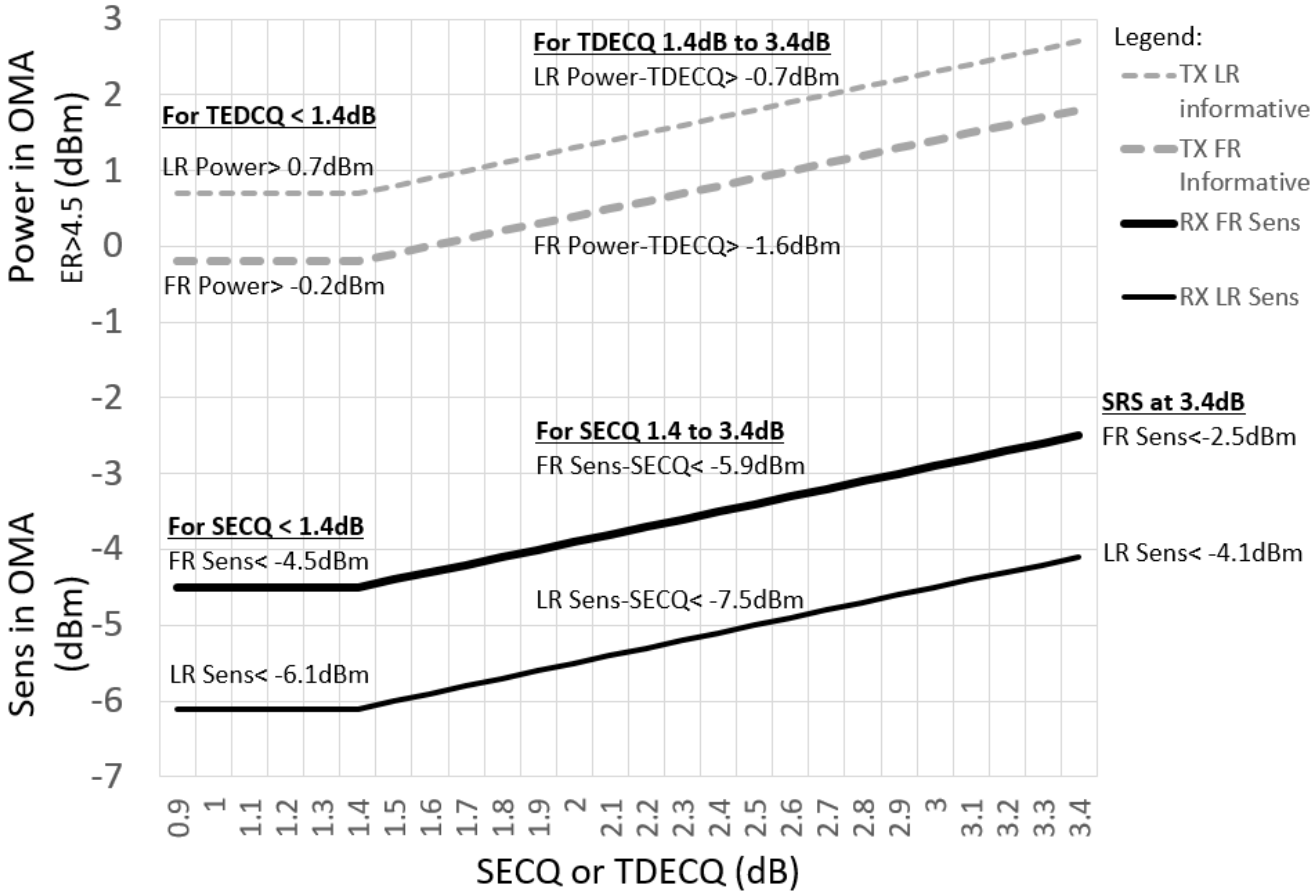


Figure 2-1: Stressed receiver sensitivity mask for 100G-FR and LR

2.1.3 100G-FR and 100G-LR illustrative link power budget

An illustrative power budget and penalties for 100G-FR and 100G-LR are shown in Table 2-4.

Table 2-4: 100G-FR and 100G-LR illustrative power budget (ER ≥ 4.5 dB)

Description	100G-FR Value	100G-LR Value	Unit
Power budget (for max TDECQ)	7.7	10.2	dB
Operating distance	2.0	10.0	km
Channel insertion loss	4.0	6.3	dB
Maximum discrete reflectance	See Table 2-5	See Table 2-5	dB
Allocation for penalties (for max TDECQ)	3.7	3.9	dB
Additional insertion loss allowed	0	0	dB

Table 2-5: 100G-FR and 100G-LR Maximum value for each discrete reflectance

Number of discrete reflectances above -55dB	Maximum value for each discrete reflectance for FR	Maximum value for each discrete reflectance for LR	Unit
1	-25	-22	dB
2	-31	-29	dB
4	-35	-33	dB
6	-38	-35	dB
8	-40	-37	dB
10	-41	-39	dB

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

Pattern	Pattern Description	Defined in[a]
Square wave	Square wave (8 threes, 8 zeroes)	120.5.11.2.4
3	PRBS31Q	120.5.11.2.2
4	PRBS13Q	120.5.11.2.1
5	Scrambled idle	119.2.4.9
6	SSPRQ	120.5.11.2.3

[a]These sub-clauses make reference to relevant clauses of IEEE Std 802.3bs™.

Table 3-2: Patterns for optical parameter testing

Parameter	***Pattern***	***Sub-clause[a]***
Wavelength	Square wave, 3, 4, 5, 6 or valid 100G-FR/LR signal	124.8.2
Side mode suppression ratio	3, 5, 6 or a valid 100G-FR/LR signal	--
Average optical power	3, 5, 6 or a valid 100G-FR/LR signal	124.8.3
Optical modulation amplitude (OMA_{outer})	4 or 6	124.8.4
Transmitter and dispersion eye closure for PAM4 (TDECQ)	6	124.8.5
Extinction ratio	4 or 6	124.8.6
$RIN_{17.1}/RIN_{15.6}$ OMA	Square wave	124.8.7
Stressed receiver conformance test signal calibration	6	124.8.9
Stressed receiver sensitivity	3 or 5	124.8.9
[a]These sub-clauses make reference to relevant clauses of IEEE Std 802.3bs™.		

3.2 SKEW AND SKEW VARIATION

The skew and skew variation is specified in IEEE Std 802.3bs™ Clause 121.3.2.

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 IEEE Std 802.3bs™ Clause 121.8.3.

3.5 OPTICAL MODULATION AMPLITUDE (OMA)

Refer to IEEE Std 802.3bs™ Clause 121.8.4.

3.6 TRANSMITTER AND DISPERSION EYE CLOSURE PENALTY (TDECQ)

TDECQ shall be within the limits given in Table 2-2 if measure using the methods specified in 121.8.5.1, 121.8.5.2 and 121.8.5.3 using a reference equalizer as described in 121.8.5.4, with the following exceptions:

- The optical return loss of the transmitter compliance channel is 17.1 (FR), 15.6 (LR) dB

- The signaling rate of the test pattern generator is as given in Table 2-2 and uses a test pattern specified for TDECQ in Table 3-2.

- The combination of the O/E converter and the oscilloscope has a fourth-order Bessel-Thomson filter response with a bandwidth of approximately 26.5625 GHz. Channel requirements

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

Table 3-3: Transmitter compliance channel specifications

Type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
100G-FR	$0.0465*\lambda*[1-(1324/\lambda)^4]$	$0.0465*\lambda*[1-(1300/\lambda)^4]$	Minimum	17.1 dB	0.8 ps
100G-LR	$0.2325*\lambda*[1-(1324/\lambda)^4]$	$0.2325*\lambda*[1-(1300/\lambda)^4]$	Minimum	15.6 dB	0.8 ps
[a] The dispersion is measured for the wavelength of the device under test (λ in nm). The coefficient assumes 2 km for 100G-FR and 10 km for 100G-LR .					
[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.					

3.6.1 Reference receiver requirements

Refer to IEEE 802.3bs™ Clause 121.8.5.1.

3.7 EXTINCTION RATIO

Extinction ratio is measured using the methods specified in IEC 61280-2-2.

3.8 RELATIVE INTENSITY NOISE (RIN)

RIN is measured using the methods specified in IEEE 802.3bs™ Clause 121.8.7.

3.9 STRESSED RECEIVER SENSITIVITY

Stressed receiver sensitivity shall be within the limits given in Table 2–3 if measured using the method defined in 121.8.9 with the following exceptions:

— The SECQ of the stressed receiver conformance test signal is measured according to 140.7.5, except that the test fiber is not used.

— The signaling rate of the test pattern generator and the extinction ratio of the E/O converter are as given in Table 2–2 using test patterns specified in Table 3–2.

— The required values of the "Stressed receiver sensitivity (OMAouter) (max)" and "Stressed eye closure for PAM4 (SECQ)" are as given in Table 2–3.

4 FIBER OPTIC CABLING MODEL

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

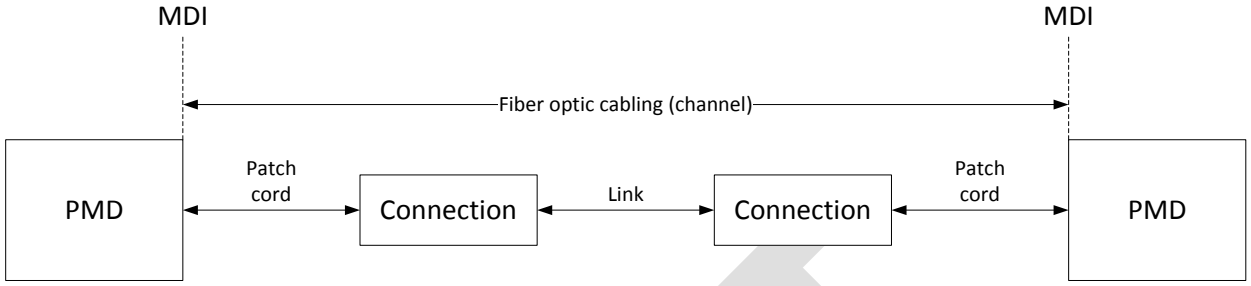


Figure 4-1: Fiber optic cabling model

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	100G-FR Values	100G-LR Values	Unit
Operating distance (max)	2	10	km
Channel insertion loss[a,b](max)	4	6.3	dB
Channel insertion loss (min)	0	0	dB
Positive dispersion[b] (max)	3.2	16.0	ps/nm
Negative dispersion[b] (min)	-3.7	-18.5	ps/nm
DGD_max[c]	3.0	8	ps
Optical return loss (min)	25	22	dB
a) These channel loss values include cable, connectors and splices.			
b) Over the wavelength range 1304.5 to 1317.5 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 100G-FR and 100G-LR 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
[a]The 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 distance for 100G-LR is based on an allocation of 2 dB total connection and splice loss. For example, this allocation supports four connections with an average insertion loss per connection of 0.5 dB. The maximum link distance for 100GBASE-FR is based on an allocation of 3 dB total connection and splice loss. 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 the value shown in Table 2-5.

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 100G-FR and 100G-LR Module Color Coding

Transceiver modules compliant to the 100G-FR and 100G-LR 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: 100G-FR and 100G-LR Module Color Coding

Color Code	Application
TBD	100G-FR
TBD	100G-LR