400GBASE-LR4 Baseline Proposal

IEEE 802.3cu Ad Hoc

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400GBASE-LR4 Baseline Proposal

- Task Force adopted objective:

  Define a four-wavelength 400 Gb/s PHY for operation over SMF with lengths up to at least 10 km

- 100 Gb/s PAM4 signaling on each of four CWDM wavelengths

- FEC in 400GBASE-R PCS layer

- 10 km reach on ITU-T G.652 category G.652.B or G.652.D SMF

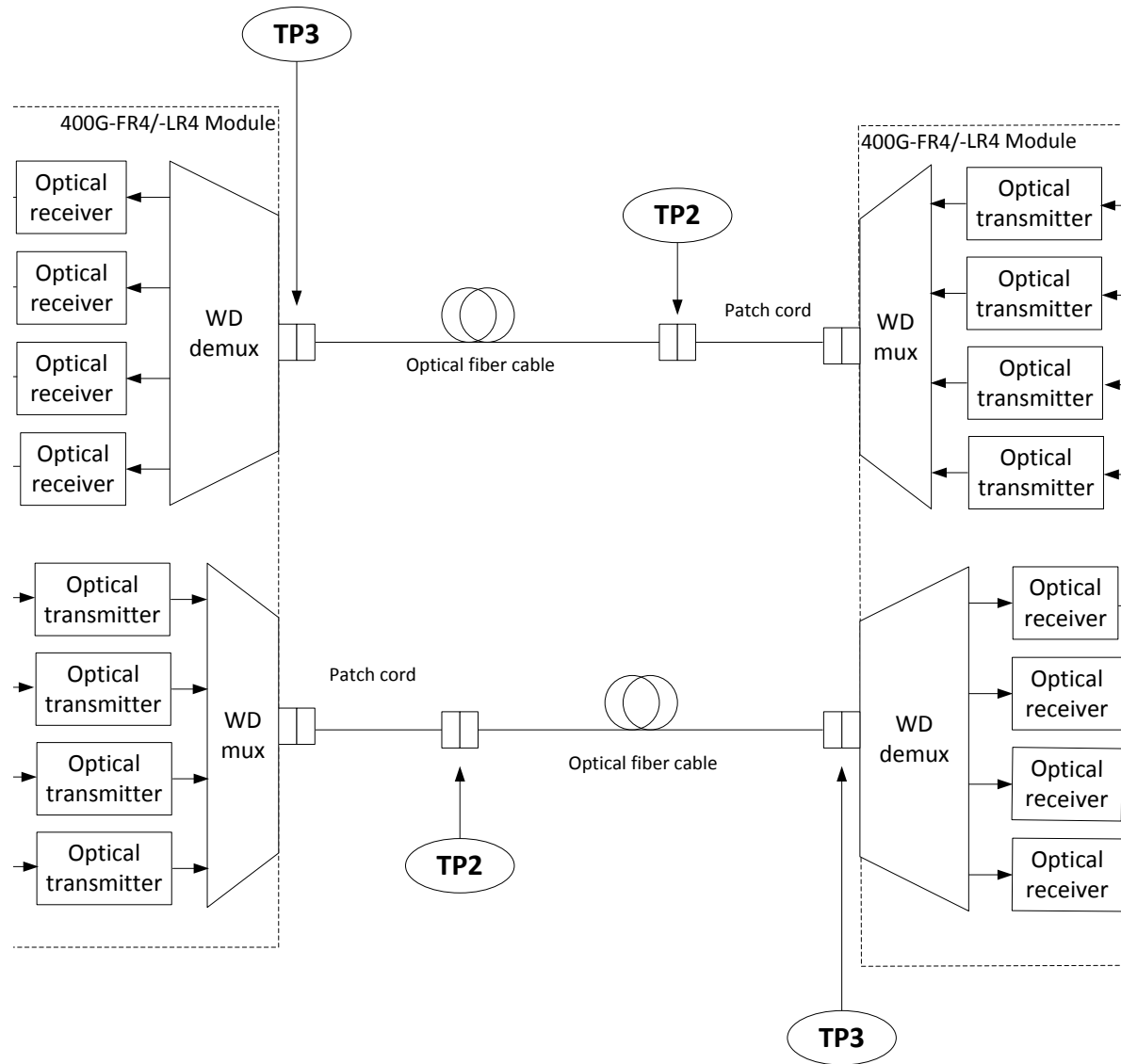# Proposed new text for "Optical fiber cable" section

Current text (from 122.11.1)

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 or the requirements in Table 122–18 where they differ.
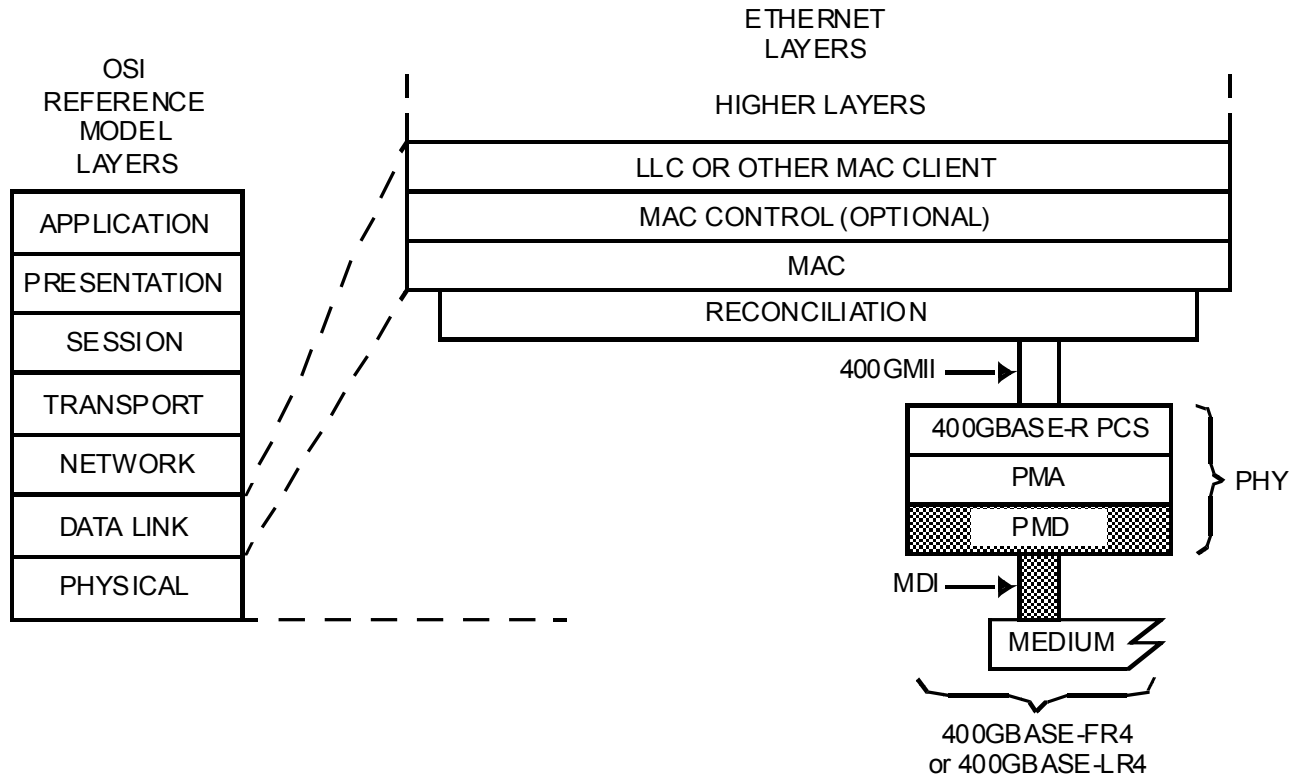
Proposed text with reference to ~~2018 version of IEC 60793-2-50~~ 2016 versions of G.652 and G.657

The fiber optic cable requirements are satisfied by cables containing ~~IEC 60793-2-50~~ ITU-T G.652 -type ~~B~~ G.652.B (dispersion unshifted), type ~~B~~ G.652.D (low water peak, dispersion unshifted), or ITU-T G.657 type ~~B~~ G.657.A1 or type ~~B~~ G.657.A2 (bend insensitive) fibers or the requirements in Table 200–14 where they differ.

Block Diagram

Position in IEEE 802.3 Ethernet Model

ETHERNET
LAYERS

OSI
REFERENCE
MODEL
LAYERS

| HIGHER LAYERS |
| LLC OR OTHER MAC CLIENT |
| MAC CONTROL (OPTIONAL) |
| MAC |
| RECONCILIATION |

| APPLICATION |
| PRESENTATION |
| SESSION |
| TRANSPORT |
| NETWORK |
| DATA LINK |
| PHYSICAL |

400GMII →

| 400GBASE-R PCS |
| PMA |
| PMD |

} PHY

MDI →

MEDIUM

400GBASE-FR4
or 400GBASE-LR4

400GMII = 400 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER

PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT

FR4 = PMD FOR SINGLE-MODE FIBER — 2 km
LR4 = PMD FOR SINGLE-MODE FIBER — 10 km

Transmit Characteristics

Description	400GBASE-LR4	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1264.5 to 1277.5	nm
	1284.5 to 1297.5	
	1304.5 to 1317.5	
	1324.5 to 1337.5	
Side-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	12.2	dBm
Average launch power, each lane (max)	6.2	dBm
Average launch power, each lane[a] (min)	-2.55	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	5.0	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane[b] (min)	0.45	dBm
Difference in launch power between any two lanes (OMA_{outer}) max	4	dB

Launch power in OMA_{outer} minus TDECQ, each lane (min):
    for extinction ratio ≥ 4.5 dB
    for extinction ratio < 4.5 dB
	-0.95
	-0.85
		dBm

Transmitter and dispersion penalty eye closure for PAM4 (TDECQ), each lane (max)	3.9	dB
TDECQ − $10*\log_{10}(C_{eq})$, each lane (max)[d]	**TBD**	dB
TDECQ − SECQ, each lane (max)	**TBD**	dB
Average launch power of OFF transmitter, each lane (max)	-20	dBm
Extinction ratio (min)	3.5	dB
Transmitter transition time (max)	17	ps
$RIN_{15.6}$ OMA (max)	-136	
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance[c] (max)	-26	dB

Receive Characteristics

Description	400GBASE-LR4	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1264.5 to 1277.5	nm
	1284.5 to 1297.5	
	1304.5 to 1317.5	
	1324.5 to 1337.5	
Damage threshold, each lane (min)[a]	7.2	dBm
Average receive power, each lane (max)	6.2	dBm
Average receive power, each lane[b] (min)	-8.85	dBm
Receive power, each lane (OMA$_{outer}$) (max)	5.0	dBm
Difference in receive power between any two lanes (OMA$_{outer}$) (max)	4.6	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA$_{outer}$), each lane[c] (max)	$RS = \max(-6.6, SECQ - 8.0)$	
Stressed receiver sensitivity (OMA$_{outer}$), each lane[d] (max)	-4.1	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ), lane under test	3.9	dB
SECQ $- 10*\log_{10}(C_{eq})$, lane under test (max)	3.9	dB
OMA$_{outer}$ of each aggressor lane	0.5	dBm

Illustrative Link Power Budget

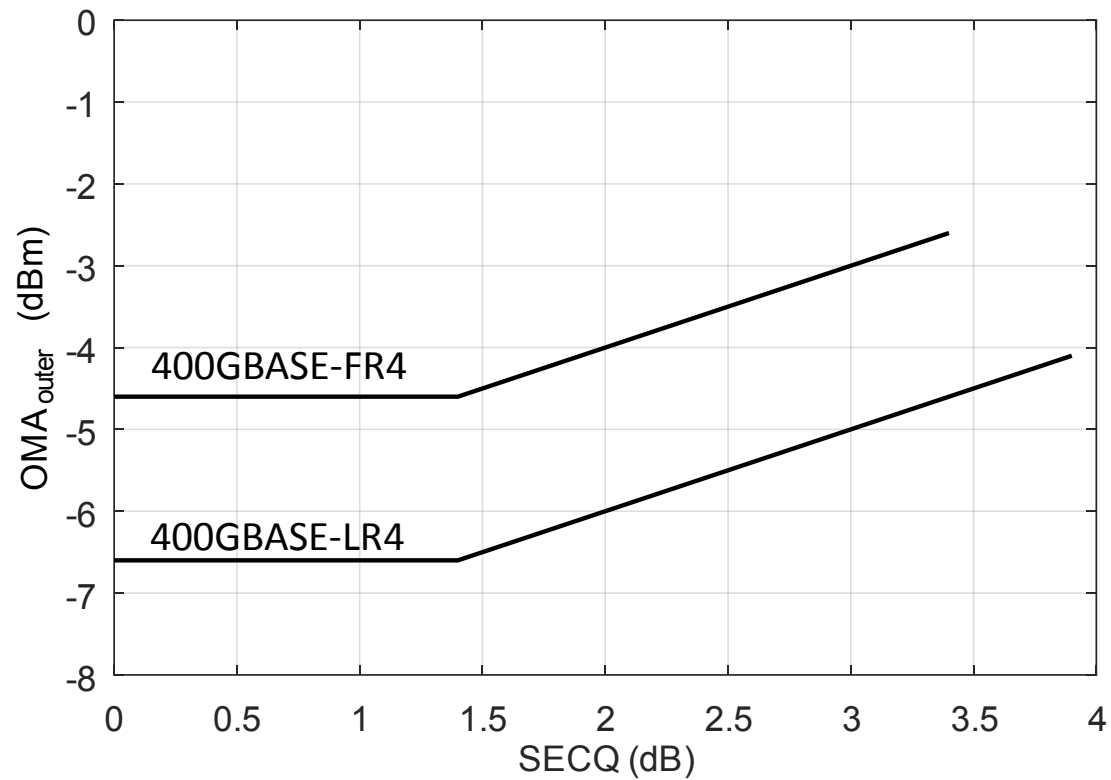| Description	400GBASE-LR4	Unit

Power budget (for max TDECQ)
    for extinction ratio ≥ 4.5 dB
    for extinction ratio < 4.5 dB
	10.95
	11.05
		dB

Operating distance	10.0	km
Channel insertion loss[a]	6.3	dB
Maximum discrete reflectance	See Table xx	dB

Allocation for penalties[b] (for max TDECQ)
    for extinction ratio ≥ 4.5 dB
    for extinction ratio < 4.5 dB
	
	4.65
	4.75
		dB

Additional insertion loss allowed	0	dB

Table xx

Number of discrete reflectance above -55dB	Maximum value for each discrete reflectance
	400GBASE-LR4
1	-22 dB
2	-29 dB
4	-33 dB
6	-35 dB
8	-37 dB
10	-39 dB

Transmitter compliance channel*

Type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
400GBASE-LR4	$0.2325*\lambda*[1-(1324/\lambda)^4]$	$0.2325*\lambda*[1-(1300/\lambda)^4]$	Minimum	15.6 dB	0.8 ps

*for TDECQ test

Illustration of receiver sensitivity mask

Fiber optic cabling (channel) characteristics

Description	400GBASE-LR4		Unit
Operating distance (max)		10	km
Channel insertion loss [a,b] (max)		6.3	dB
Channel insertion loss (min)	0		dB
Positive dispersion[b] (max)		33.4	ps/nm
Negative dispersion[b] (min)		-59.4	ps/nm
DGD_max[c]		5	ps
Optical return loss (min)		22	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.			

Optical fiber and cable characteristics

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The fiber optic cable requirements are satisfied by cables containing ~~IEC 60793-2-50 type B –~~ ITU-T G.652.B (dispersion unshifted), type ~~B~~ G.652.D (low water peak, dispersion unshifted), or type ~~B~~ G.657.A1, or type ~~B~~ G.657.A2 (bend insensitive) fibers, or the requirements in Table 200–14 where they differ.

| Description	Value	Unit
Nominal fiber specification wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.47^a or 0.5^b	dB/km
Zero dispersion wavelength (λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope (max) (S_0)	0.092	ps/nm^2km
[a] The 0.47 dB/km attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695. [b] The 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3.		

400GBASE-LR4 Baseline

Thank you
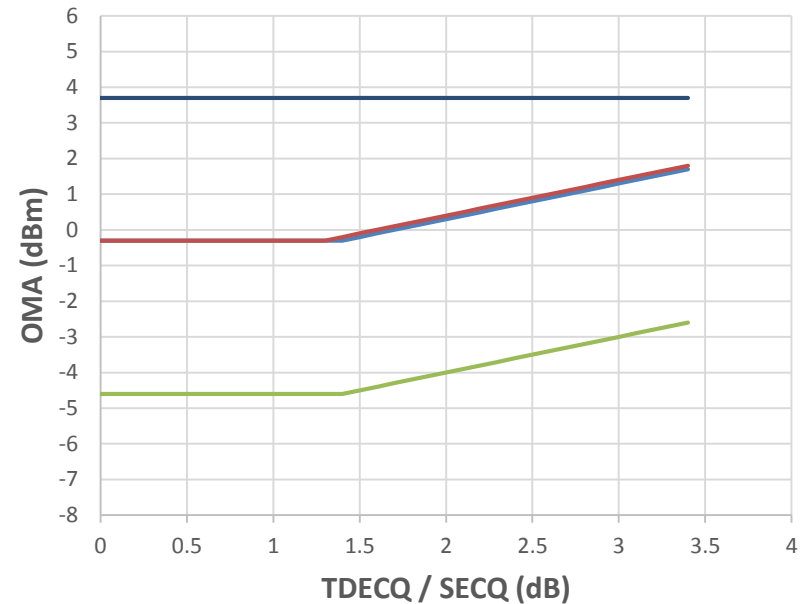
Backup - Compare LR4 with FR4

LR4 requires 2.75 dB additional link budget compared to FR4. This is allocated 0.75 dB to the Tx and 2.0 dB to the Rx.

400GBASE-LR4 TxOMA (min) and RS (max) versus TDECQ/SECQ
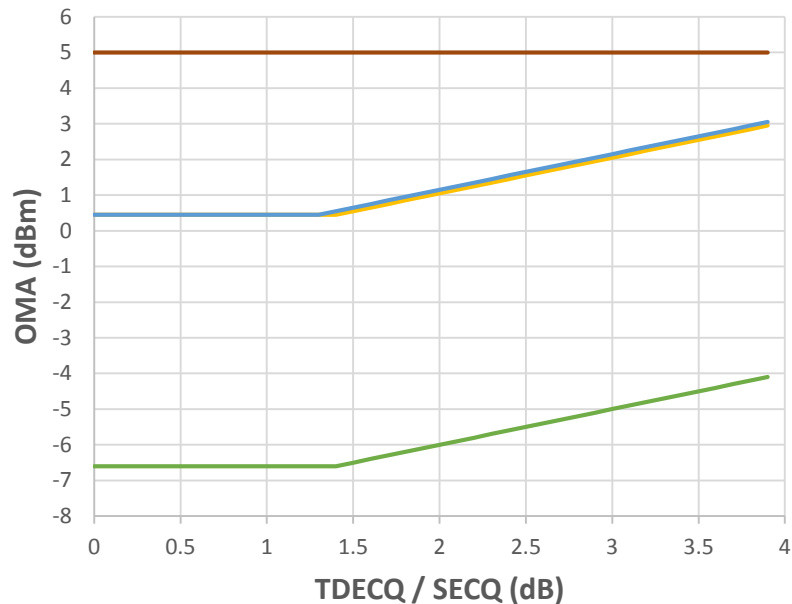
400GBASE-FR4 TxOMA (min) and RS (max) versus TDECQ/SECQ