



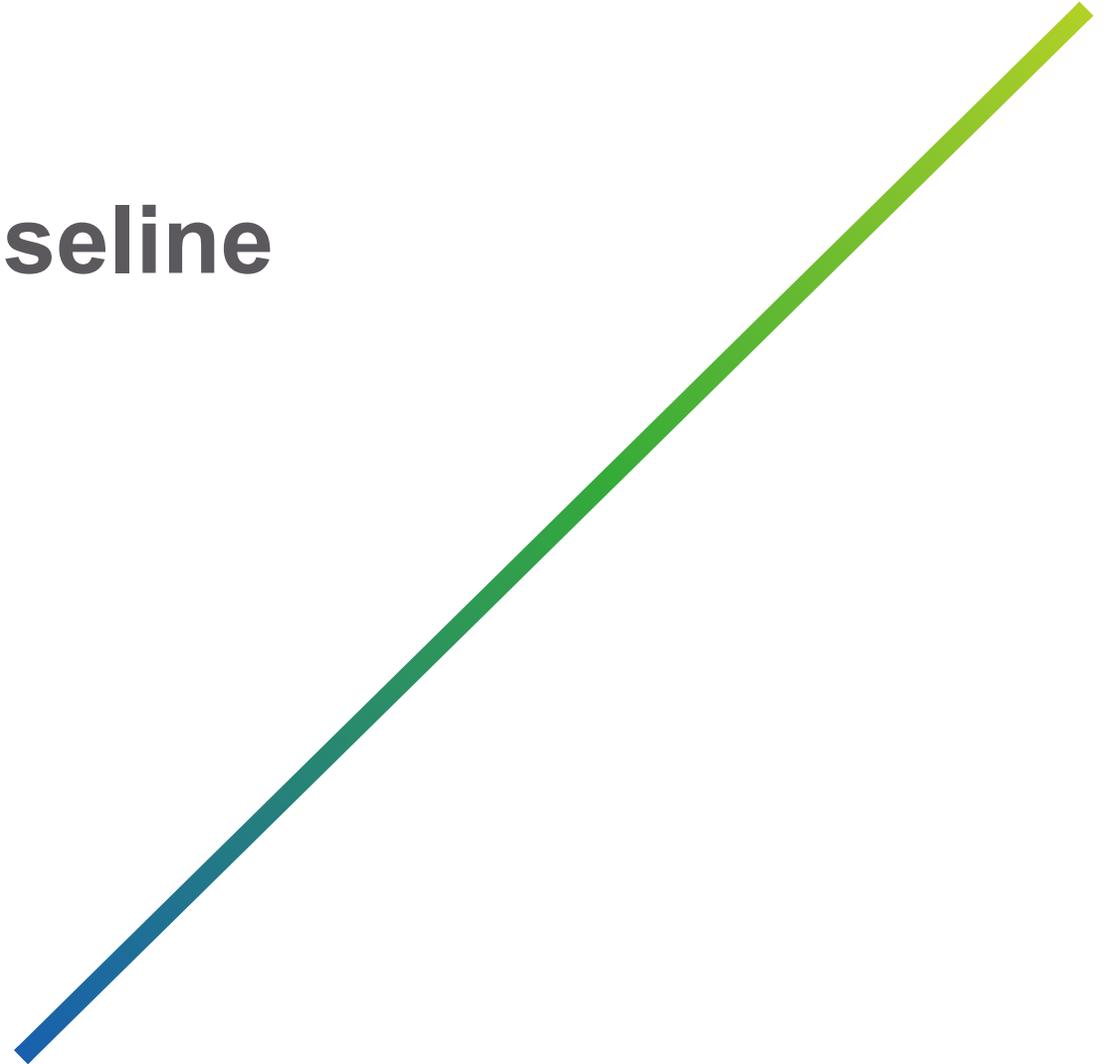
400GBASE-LR4 (7 km) Baseline Proposal

IEEE P802.3cu Task Force meeting

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400GBASE-LR4 Baseline Proposal(s)

- Task Force adopted objective:
Define a four-wavelength 400 Gb/s PHY for operation over SMF with lengths up to at least 10 km
- This proposal:
7 km reach with 11 dB power budget with 6.3 dB insertion loss and 4.7 dB for penalties.
Penalties include 3.9 dB TDECQ, 0.5 dB MPI, 0.3 dB DGD.

(If adopted, this would require a change in the objective too. Not discussed in this presentation.)

Transmit Characteristics

Table 151-7—400GBASE-FR4 and 400GBASE-LR4 transmit characteristics

Description	400GBASE-FR4	400GBASE-LR4	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane 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)	9.5	12.2	dBm
Average launch power, each lane (max)	3.5	6.2	dBm
Average launch power, each lane ^a (min)	-3.3	-2.5	dBm
Outer Optical Modulation Amplitude (OMA _{outer}), each lane (max)	3.7	5	dBm
Outer Optical Modulation Amplitude (OMA _{outer}), each lane (min) ^b	-0.3	0.5	dBm
Difference in launch power between any two lanes (OMA _{outer}) (max)	4	4	dB
Launch power in OMA _{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	-1.7 -1.6	-0.9 -0.8	dBm dBm
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max)	3.4	3.9	dB
TDECQ - 10log ₁₀ (C _{eq}) ^c (max)	3.4	3.9	dB
Average launch power of OFF transmitter, each lane (max)	-20	-20	dBm
Extinction ratio, each lane (min)	3.5	3.5	dB
Transmitter transition time (max)	17		ps
RIN _{17,1} OMA (max)	-136	—	dB/Hz
RIN _{15,6} OMA (max)	—	-136	dB/Hz
Optical return loss tolerance (max)	17.1	15.6	dB
Transmitter reflectance ^d (max)	-26		dB

^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 OMA_{outer} (min) must exceed this value.

^c C_{eq} is a coefficient defined in 121.8.5.3, which accounts for reference equalizer noise enhancement.

^d Transmitter reflectance is defined looking into the transmitter.

Table 151–8—400GBASE-FR4 and 400GBASE-LR4 receive characteristics

Description	400GBASE-FR4	400GBASE-LR4	Unit
Signaling rate, each lane (range)	53.125 ± 100 ppm		GBd
Modulation format	PAM4		—
Lane 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 ^a , each lane	4.5	7.2	dBm
Average receive power, each lane (max)	3.5	6.2	dBm
Average receive power, each lane ^b (min)	-7.3	-8.8	dBm
Receive power (OMA _{outer}), each lane (max)	3.7	5	dBm
Difference in receive power between any two lanes (OMA _{outer}) (max)	4.1	4.6	dB
Receiver reflectance (max)	-26		dB
Receiver sensitivity (OMA _{outer}), each lane ^c (max)	Equation (151-1)	Equation (151-2)	dBm
Stressed receiver sensitivity (OMA _{outer}), each lane ^d (max)	-2.6	-4.1	dBm
Conditions of stressed receiver sensitivity test: ^e			
Stressed eye closure for PAM4 (SECQ), lane under test	3.4	3.9	dB
SECQ - 10log ₁₀ (C _{eq}), lane under test (max)	3.4	3.9	dB
OMA _{outer} of each aggressor lane	1.5	0.5	dBm

^a The receiver shall be able to tolerate, without damage, continuous exposure to an optical input 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 Receiver sensitivity (OMA_{outer}), each lane (max) is informative and is defined for a transmitter with a value of SECQ up to 3.4 dB for 400GBASE-FR4 and up to 3.9 dB for 400GBASE-LR4.

^d Measured with conformance test signal at TP3 (see 151.8.10) for the BER specified in 151.1.1.

^e These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

Receive Characteristics

$$RS = \max(-4.6, SECQ - 6) \text{ (dBm)} \quad (151-1)$$

$$RS = \max(-6.6, SECQ - 8) \text{ (dBm)} \quad (151-2)$$

where

RS

is the receiver sensitivity

SECQ

is the SECQ of the transmitter used to measure the receiver sensitivity

Tables for 7 km –LR4 PMD

Table 151-6—400GBASE-FR4 and 400GBASE-LR4 operating ranges

PMD type	Required operating range
400GBASE-FR4	2 m to 2 km
400GBASE-LR4	2 m to 7 km

Table 151-9—400GBASE-FR4 and 400GBASE-LR4 illustrative link power budgets

Parameter	400GBASE-FR4	400GBASE-LR4	Unit
Power budget (for maximum TDECQ): for extinction ratio \geq 4.5 dB for extinction ratio $<$ 4.5 dB	7.7	11	dB
	7.8	11.1	dB
Operating distance	2	7	km
Channel insertion loss	4 ^a	5.5 ^b	dB
Maximum discrete reflectance	See 151.11.2.2	See 151.11.2.2	dB
Allocation for penalties ^c (for maximum TDECQ): for extinction ratio \geq 4.5 dB for extinction ratio $<$ 4.5 dB	3.7	4.7	dB
	3.8	4.8	dB
Additional insertion loss allowed	0	0.8	dB

^a The channel insertion loss is calculated using the maximum distance specified in Table 151-6 for 400GBASE-FR4 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 151.11.2.1.

^b The channel insertion loss is calculated using the maximum distance specified in Table 151-6 for 400GBASE-LR4 and fiber attenuation of 0.5 dB/km plus an allocation for connection and splice loss given in 151.11.2.1.

^c Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Table 151-12—Transmitter compliance channel specifications

PMD type	Dispersion ^a (ps/nm)		Insertion loss ^b	Optical return loss ^c	Max mean DGD
	Minimum	Maximum			
400GBASE-FR4	$0.0465 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.0465 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	Minimum	17.1 dB	0.8 ps
400GBASE-LR4	$0.161 \cdot \lambda \cdot [1 - (1324 / \lambda)^4]$	$0.161 \cdot \lambda \cdot [1 - (1300 / \lambda)^4]$	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 400GBASE-FR4 and 7 km for 400GBASE-LR4.

^b There is no intent to stress the sensitivity of the O/E converter associated with the oscilloscope.

^c The optical return loss is applied at TP2.

Table 151-13—Fiber optic cabling (channel) characteristics

Description	400GBASE-FR4	400GBASE-LR4	Unit
Operating distance (max)	2	7	km
Channel insertion loss ^{a,b} (max)	4	6.3	dB
Channel insertion loss (min)	0	0	dB
Positive dispersion ^b (max)	6.7	23.2	ps/nm
Negative dispersion ^b (min)	-11.9	-41.1	ps/nm
DGD_max ^c	2.3	5	ps
Optical return loss (min)	25	22	dB

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

^b Over the wavelength range 1264.5 nm to 1337.5 nm for 400GBASE-FR4 and 400GBASE-LR4.

^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.

Summary

- Proposed 400GBASE-LR4 (7 km) baseline:
 - Same Tx and Rx characteristics as [lewis_3cu_01_0719](#).
 - 7 km reach on worst-case G.652 fiber limits dispersion to a range of -41.1 to +23.2 ps/nm
 - Helps with keeping TDECQ under 3.9 dB
 - Channel insertion loss of 6.3 dB allows the use of 0.5 dB/km cables with up to 2.8 dB for connectors.