

# Towards a 400GBASE-LR4 Baseline

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As updated based on comments at meeting

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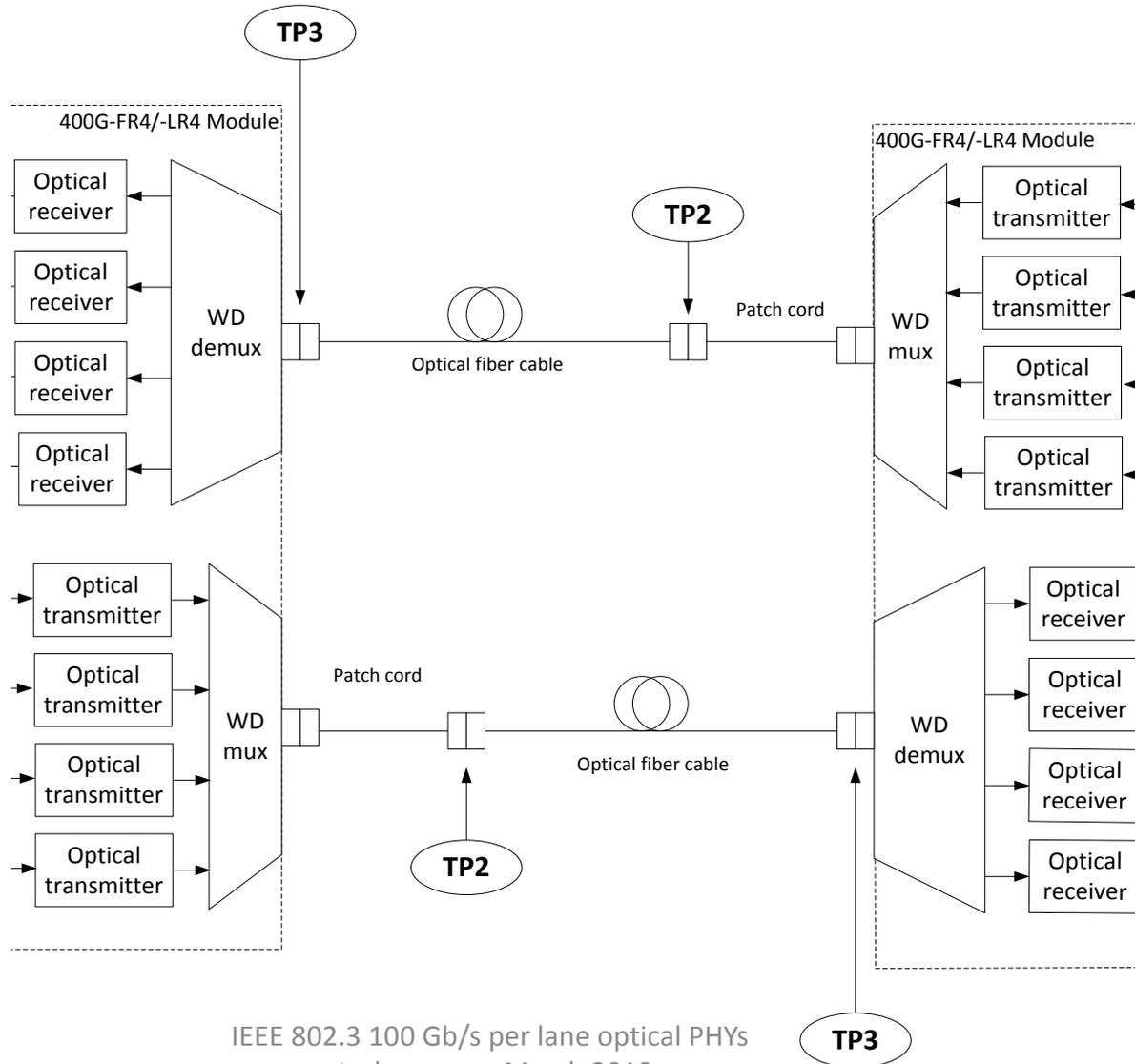
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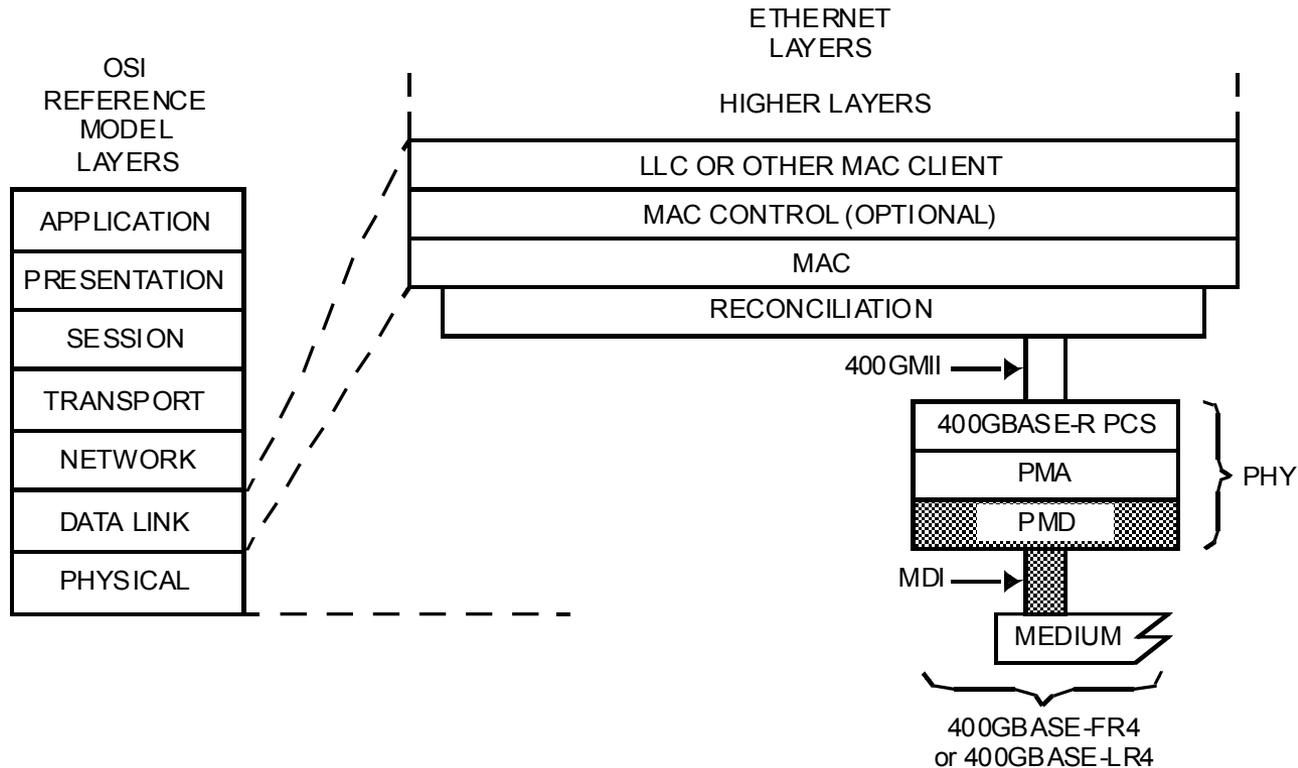
# Overview

- This presentation describes a set of values for the Study Group adopted objective:
  - *Define a four-wavelength 400 Gb/s PHY for operation over SMF with lengths up to at least 10 km*
- Based on 100 Gb/s PAM4 signaling on each of four CWDM wavelengths
- Relies on the FEC in 400GBASE-R PCS layer.

# Block Diagram



# Position in IEEE 802.3 Ethernet Model



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)	10.0	dBm
Average launch power, each lane (max)	4.0	dBm
Average launch power, each lane <sup>a</sup> (min)	-2.8	dBm
Outer Optical Modulation Amplitude (OMA <sub>outer</sub> ), each lane (max)	4.2	dBm
Outer Optical Modulation Amplitude (OMA <sub>outer</sub> ), each lane <sup>b</sup> (min)	0.2	dBm
Difference in launch power between any two lanes (OMA <sub>outer</sub> ) max	4	dB
Launch power in OMA <sub>outer</sub> minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	-1.2 -1.1	dBm
Transmitter and dispersion penalty eye closure for PAM4 (TDECQ), each lane (max)	3.9	dB
TDECQ – 10*log <sub>10</sub> (C <sub>eq</sub> ), each lane (max) <sup>d</sup>	3.9	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 <sub>15,6</sub> OMA (max)	-136	
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance <sup>c</sup> (max)	-26	dB

# Transmitter compliance channel (for TDECQ test)

Type	Dispersion <sup>a</sup> (ps/nm)		Insertion loss <sup>b</sup>	Optical return loss <sup>c</sup>	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

# Fiber optic cabling (channel) characteristics

Description	400GBASE-LR4	Unit
Operating distance (max)	10	km
Channel insertion loss <sup>a,b</sup> (max)	6.3	dB
Channel insertion loss (min)	0	dB
Positive dispersion <sup>b</sup> (max)	33.5	ps/nm
Negative dispersion <sup>b</sup> (min)	-59.5	ps/nm
DGD_max <sup>c</sup>	10	ps
Optical return loss (min)	<del>21</del> 22	dB
<sup>a</sup> These channel loss values include cable, connectors and splices.		
<sup>b</sup> Over the wavelength range 1264.5 to 1337.5 nm.		
<sup>c</sup> 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

Description	Value	Unit
Nominal fiber specification wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.47 <sup>a</sup> or 0.5 <sup>b</sup>	dB/km
Zero dispersion wavelength ( $\lambda_0$ )	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope (max) ( $S_0$ )	0.093	ps/nm <sup>2</sup> km

<sup>a</sup> The 0.47 dB/km attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695.  
<sup>b</sup> The 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3.

# 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) <sup>a</sup>	5.0	dBm
Average receive power, each lane (max)	4.0	dBm
Average receive power, each lane <sup>b</sup> (min)	-9.1	dBm
Receive power, each lane (OMA <sub>outer</sub> ) (max)	4.2	dBm
Difference in receive power between any two lanes (OMA <sub>outer</sub> ) (max)	<del>4.1</del> 4.6	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA <sub>outer</sub> ), each lane <sup>c</sup> (max)	$RS = \max(-6.6, SECQ - 8.0)$	
Stressed receiver sensitivity (OMA <sub>outer</sub> ), each lane <sup>d</sup> (max)	-4.1	dBm
<b>Conditions of stressed receiver sensitivity test:</b>		
Stressed eye closure for PAM4 (SECQ), lane under test	3.9	dB
SECQ – 10*log <sub>10</sub> (C <sub>eq</sub> ), lane under test (max)	3.9	dB
OMA <sub>outer</sub> of each aggressor lane	<del>0</del> 0.5	dBm

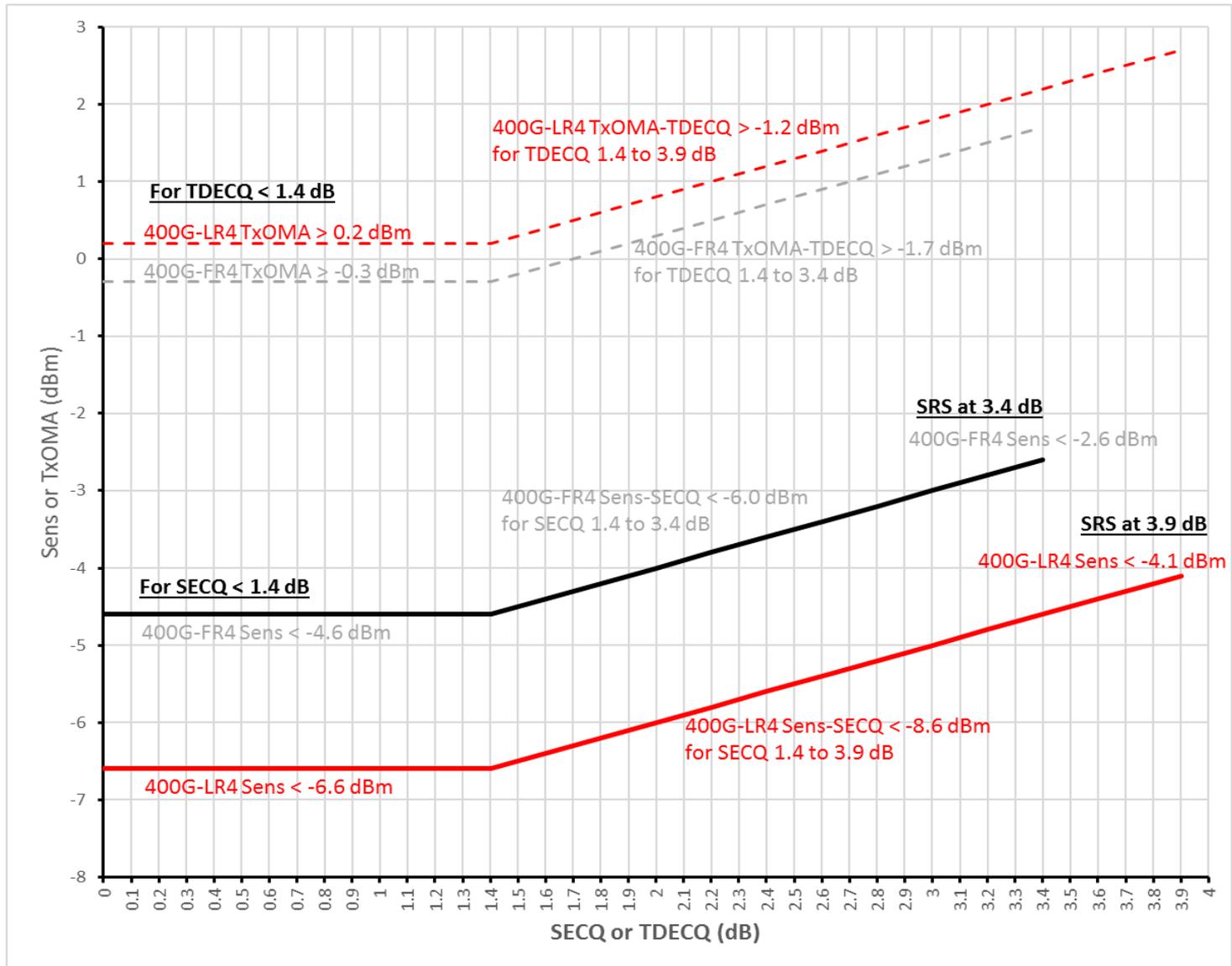
# Illustrative Link Power Budget

Description	400GBASE-LR4	Unit
Power budget (for max TDECQ) for extinction ratio $\geq 4.5$ dB for extinction ratio $< 4.5$ dB	10.7 10.8	dB
Operating distance	10.0	km
Channel insertion loss <sup>a</sup>	6.3	dB
Maximum discrete reflectance	See Table xx	dB
Allocation for penalties <sup>b</sup> (for max TDECQ) for extinction ratio $\geq 4.5$ dB for extinction ratio $< 4.5$ dB	4.4 4.5	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

# Illustration of receiver sensitivity mask



# Thanks