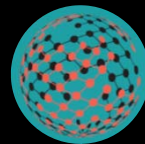




An Approach To 25GbE SMF 10km Specification

20160314 – IEEE Plenary (Macau)

Kohichi Tamura

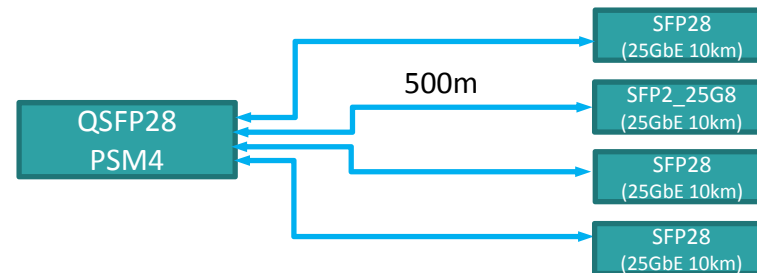


Reviewers / Supporters

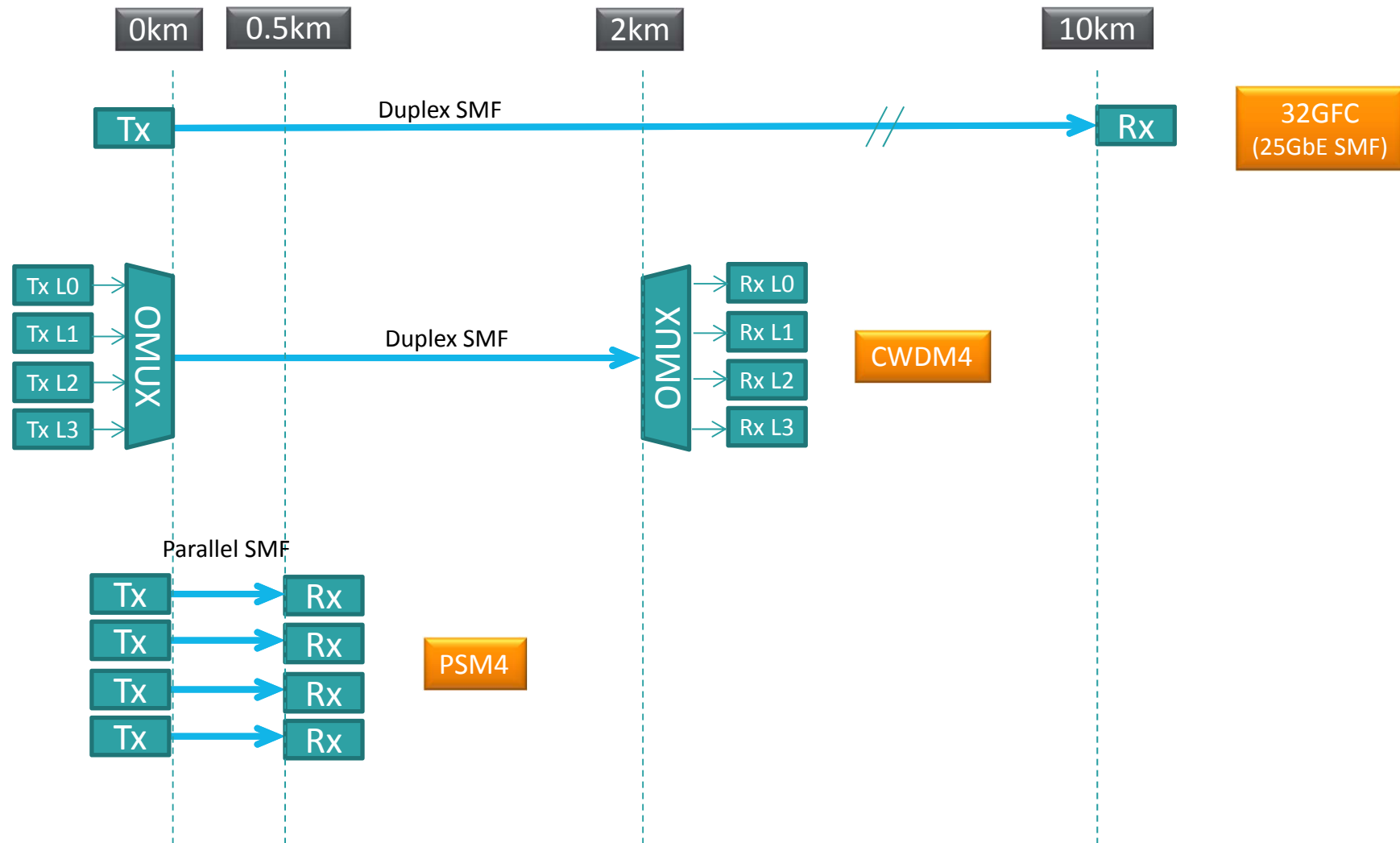
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- Peter Stasser, Huawei
- Brian Welch, Luxtera
- Ryan Latchman, Macom
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- Jeff Maki, Juniper Networks
- Bharat Tailor, Semtech
- Mark Kimber, Semtech
- David Malicoat, HPE

Considerations

1. Purpose is to survey existing specs and explore one way to merge them for broad market potential. Not intended to be TF discussion.
2. Existing specifications
 1. 32GFC (28.05Gbps over 10km) - already suggested
 2. CWDM4 (4 λ WDM of 25.8Gbps/lane over 2km) – this presentation
 1. Link budget of 8dB almost enough for 10km (9.3dB)
 2. Start with CWDM4 Tx and revise Rx for additional 1.3dB link budget
3. Interoperability application
 1. PSM4 breakout (see lewis_01_022416_25gsmf.pdf, tamura_160302_10km_25GSMF_adhoc.pdf)
 1. Wavelength range (match PSM4)
 2. Power levels (OMA, P_{avg})



Existing 25G/Lane Specifications With FEC



25GbE-10km Illustrative Link Power Budget

Parameter	Units	32GFC	CWDM4	PSM4	Possible 25GbE-10km Spec
Power budget (for max TDP)	dB	9.04	8	6.2	9.3
Operating distance	km	10	2	0.5	10
Channel insertion loss	dB	6.34 ^a	5	3.3	6.3 ^b
Maximum discrete reflectance	dB	-	-26	-35	-26
Allocation for penalties (for max TDP)	dB	2.7	3	2.9	3
Additional insertion loss allowed	dB	0	0	0	0

^a For 32GFC at 10km and 2.0dB connection loss

^b Same as 100GBASE-LR4. Fiber loss of 4.3dB + connection loss of 2dB.

Fiber Attenuation

Ref: "IEEE Standard For Ethernet – Section 6" Clause 88

Table 88–15—Optical fiber and cable characteristics

Description	Value	Unit
Nominal fiber specification wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.43 ^a or 0.5 ^b	dB/km
Zero dispersion wavelength (λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope (max) (S_0)	0.093	ps/nm ² km

^aThe 0.43 dB/km at 1295 nm attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695.
^bThe 0.5 dB/km attenuation is provided for Outside Plant cable as defined in ANSI/TIA 568-C.3. Using 0.5 dB/km may not support operation at 10 km for 100GBASE-LR4 or 40 km for 100GBASE-ER4.

Ref: Appendix I of ITU-T G.695 Optical Interfaces For Course Wavelength Division Multiplexing Applications

Table I.1 – Assumed attenuation coefficient values

Nominal central wavelength (nm)	ITU-T G.652.A and ITU-T G.652.B cable		ITU-T G.652.C and ITU-T G.652.D cable	
	Minimum attenuation coefficient (dB/km)	Maximum attenuation coefficient (dB/km)	Minimum attenuation coefficient (dB/km)	Maximum attenuation coefficient (dB/km)
1271	0.392	0.473	0.385	0.470
1291	0.370	0.447	0.365	0.441
1311	0.348	0.423	0.352	0.423
1331	0.331	0.425	0.340	0.411
1351	0.320	0.476	0.329	0.399
1371			0.316	0.386
1391			0.301	0.372
1411			0.285	0.357
1431	0.263	0.438	0.269	0.341
1451	0.250	0.368	0.254	0.326
1471	0.238	0.327	0.240	0.312
1491	0.229	0.303	0.229	0.300
1511	0.221	0.290	0.220	0.290
1531	0.215	0.283	0.213	0.283
1551	0.211	0.278	0.209	0.277
1571	0.208	0.276	0.208	0.273
1591	0.208	0.278	0.208	0.275
1611	0.208	0.289	0.212	0.283

NOTE – These coefficient values include an allowance for maximum central wavelength deviation.

Highest loss at 1295nm. Interpolate attenuation at 1295nm of 0.43dB/km

Channel loss:

- Fiber: 4.3dB (10x0.43)
- Connectors: 2dB
- Total: 6.3dB

100GBASE-LR4/ER4

Ref: "IEEE Standard For Ethernet – Section 6"
Clause 88: 100GBASE-LR4, ER4

Table 88–5—Wavelength-division-multiplexed lane assignments

Lane	Center frequency	Center wavelength	Wavelength range
L ₀	231.4 THz	1295.56 nm	<u>1294.53</u> to 1296.59 nm
L ₁	230.6 THz	1300.05 nm	1299.02 to 1301.09 nm
L ₂	229.8 THz	1304.58 nm	1303.54 to 1305.63 nm
L ₃	229 THz	1309.14 nm	1308.09 to <u>1310.19</u> nm

25GbE-10km proposal:
• 1295-1325 nm

Table 88–9—100GBASE-LR4 and 100GBASE-ER4 illustrative link power budgets

Parameter	<u>100GBASE-LR4</u>	100GBASE-ER4		Unit
Power budget (for maximum TDP)	8.5	—		dB
Power budget	—	21.5		dB
Operating distance	10	30	40 ^a	km
<u>Channel insertion loss</u>	<u>6.3^b</u>	15	18	dB
Maximum discrete reflectance	–26	–26		dB
<u>Allocation for penalties^c (for maximum TDP)</u>	<u>2.2</u>	—		dB
Allocation for penalties ^c	—	3.5		
Additional insertion loss allowed	0	3	0	dB

^aLinks longer than 30 km are considered engineered links. Attenuation for such links needs to be less than the worst case for B1.1, B1.3, or B6_a single-mode cabled optical fiber

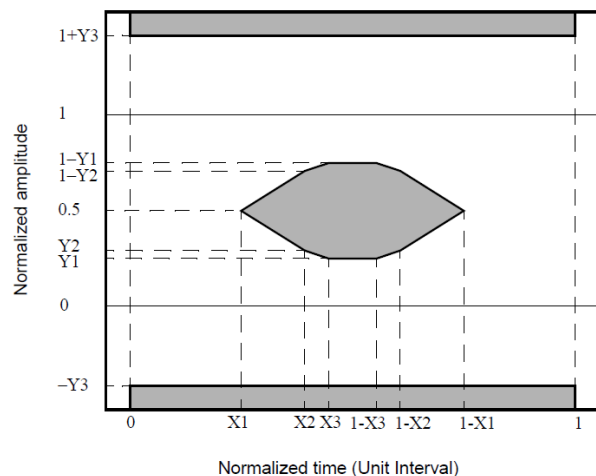
^bThe channel insertion loss is calculated using the maximum distance specified in Table 88–6 for 100GBASE-LR4 and fiber attenuation of 0.43 dB/km at 1295 nm plus an allocation for connection and splice loss given in 88.11.2.1.

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

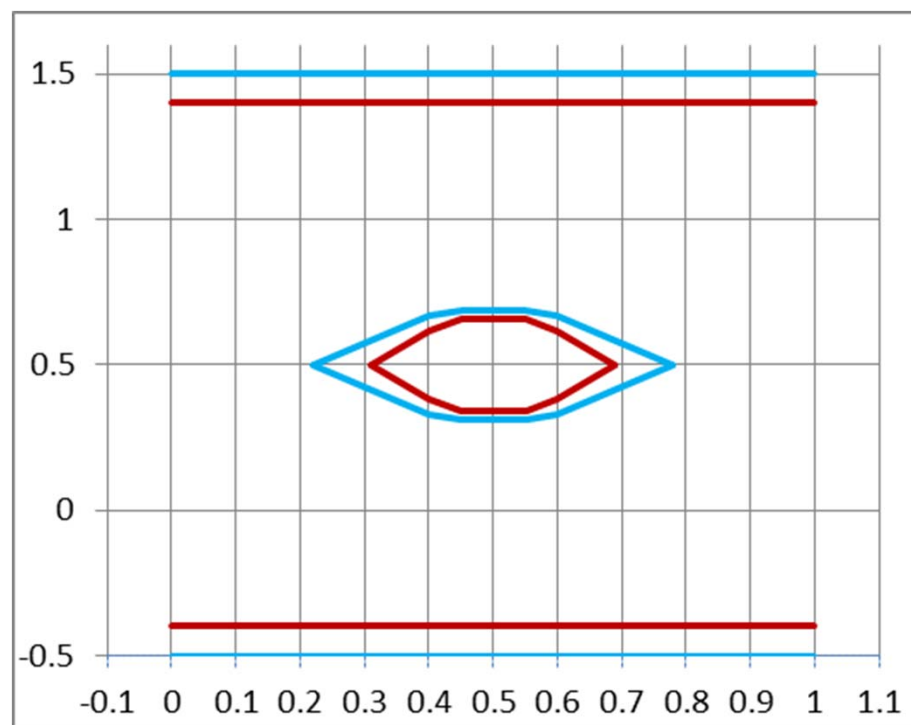
25GbE-10km Transmit Characteristics

Description	Units	32GFC	CWDM4	PSM4	Possible 25GbE-10km Spec
Operating range (max)	km	10	2	0.5	10
Signaling rate	Gbps	28.05	25.78125	25.78125	25.78125
Operating BER		1.0×10^{-6}	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}
Wavelength (max)	nm	1325	1337.5	1325	1325
Wavelength (min)	nm	1295	1264.5	1295	1295
Average launch power (max)	dBm	2	2.5	2	2.5
Average launch power (min)	dBm	-5	-6.5	-9.4	-6.5
OMA (max)	dBm	-	2.5	2.2	2.5
OMA (min)	dBm	-2	-4	-	-4
Launch power in OMA minus TDP (min)	dBm	-5	-5	-7.25 (center) ^a -3.4 (edge) ^a	-5
Transmitter and dispersion penalty (max)	dB	2.7	3	2.9	3
Extinction ratio (min)	dB	4	3.5	3.5	3.5
Transmitter eye mask	{X1,X2,X3, Y1,Y2,Y3}	{0.22, 0.4, 0.45, 0.31, 0.33, 0.5}	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}

Tx Eye Mask Comparison: 32GFC and CWDM4/PSM4



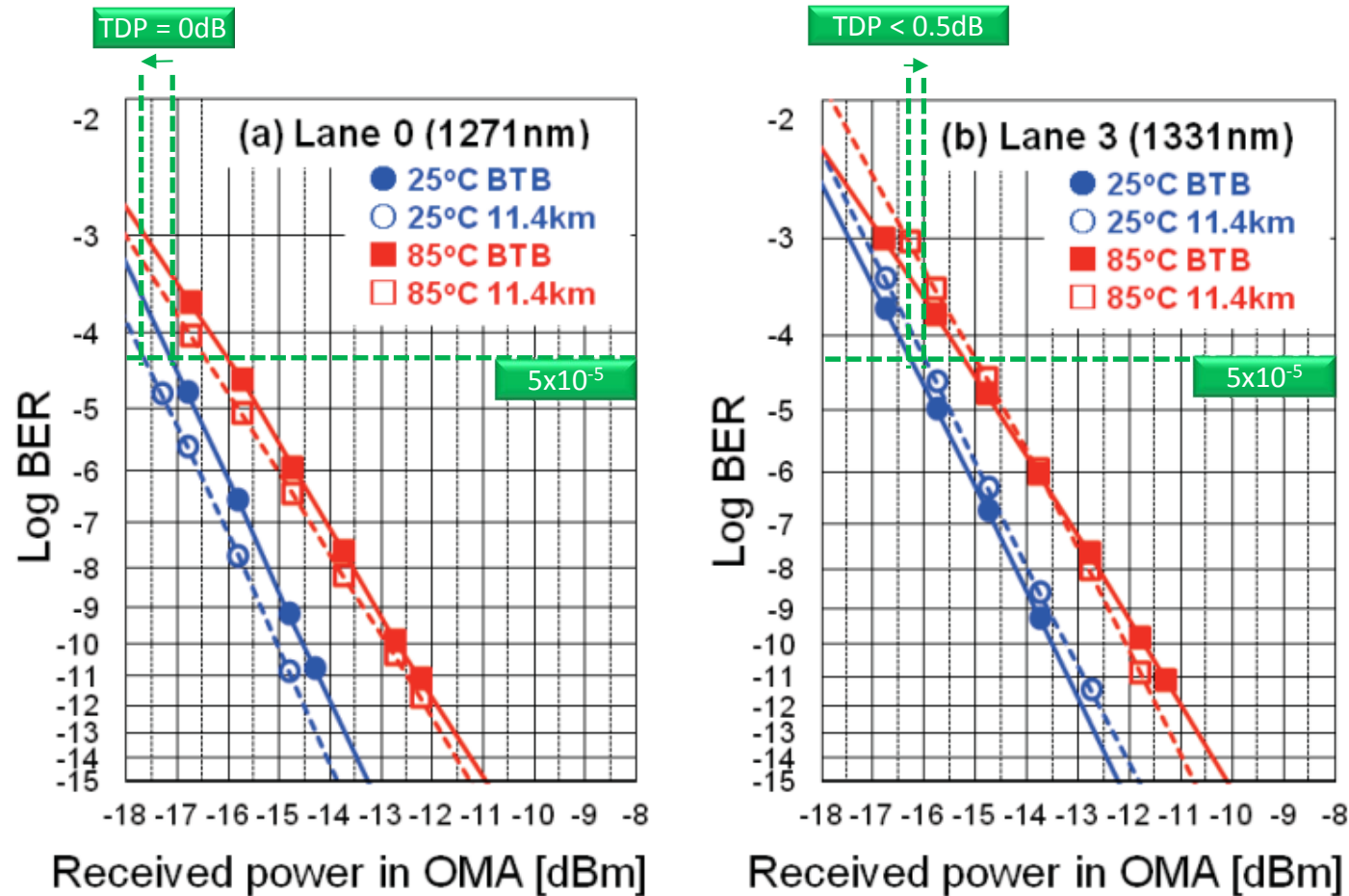
Parameter	32GFC (UI)	CWDM4/PSM4 (UI)
X1	0.22	0.31
X2	0.40	0.40
X3	0.45	0.45
Y1	0.31	0.34
Y2	0.33	0.38
Y3	0.50	0.40



— 32GFC
— CWDM4/PSM4

CWDM4/PSM4 eye mask better for low cost

TDP for 10km DML (Example)



Ref: T. Nakajima et al., OFC 2015, Th1G.6

- DML TOSA + PIN ROSA at edges of CWDM4 wavelength band.
- Suggests TDP of 3dB can be reduced.

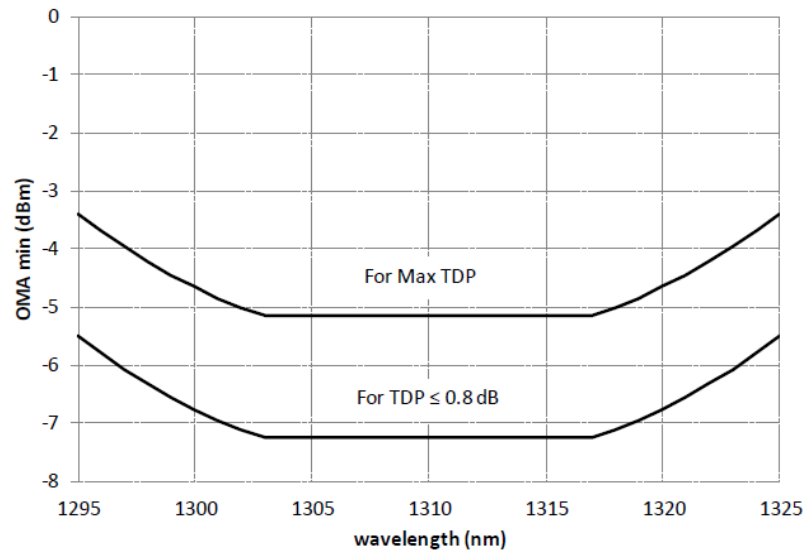
25GbE-10km Receive Characteristics

Description	Units	32GFC	CWDM4	PSM4	Possible 25GbE-10km Spec
Signaling rate	Gbps	28.05	25.78125	25.78125	25.78125
Operating BER		1.0×10^{-6}	5.0×10^{-5}	5.0×10^{-5}	5.0×10^{-5}
Receiver reflectance (max)	dB	-26	-26	-26	-26
Avg. received power (max)	dBm	2.0	2.5	2.0	2.5
Receiver sensitivity (OMA, max)	dBm	-11.4	-10	-11.35 (center) -9.6 (edge)	-11.3
Stressed receiver sensitivity (OMA, max)	dBm	-9.2	-7.3	-8.79 (center) -7.04 (edge)	TBD
Conditions of stressed receiver sensitivity test	VEP J2: J4:	-	1.9 0.33 UI 0.48 UI	1.9 0.27 UI 0.39 UI	TBD
SRS eye mask definition	{X1,X2,X3, Y1,Y2,Y3}	-	{0.39, 0.5, 0.5, 0.39, 0.39, 0.4}	{0.24, 0.5, 0.5, 0.24, 0.24, 0.4}	TBD

PSM4 Transmit & Receive Characteristics

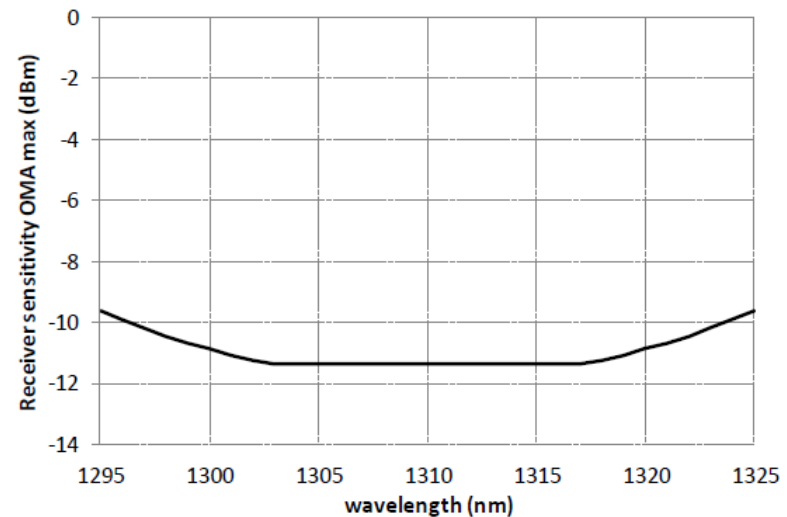
$$Tx_{OMA} \geq \text{MAX} \left(-8.55 + \frac{(\lambda - 1310)^2}{100}, -8.05 \right) + \text{MAX} (TDP, 0.8) \text{ dBm}$$

$$Rx_{sens} \leq \text{MAX} \left(-11.85 + \frac{(\lambda - 1310)^2}{100}, -11.35 \right) \text{ dBm}$$



Transmitter Minimum OMA

TDP (dB)	Tx OMA-TDP min (dBm)	Tx OMA-TDP max (dBm)
0.8	-7.25	-5.5
2.9	-5.15	-3.4

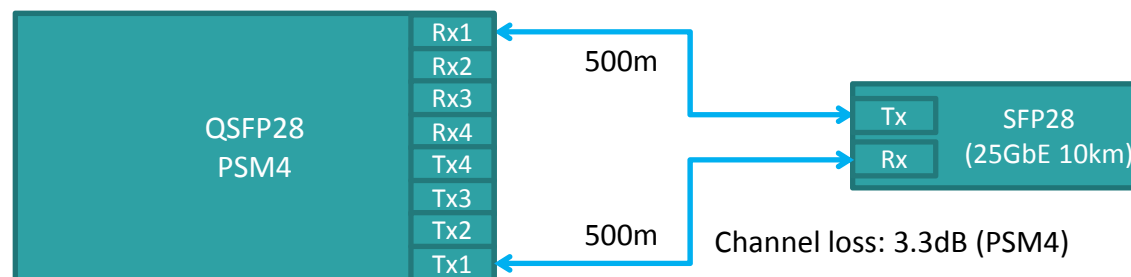


Receiver Sensitivity

Rx Sensitivity OMA	Min (dBm)	Max (dBm)
	-11.35	-9.6

Ref: "100G PSM4 Specification V2.0" from www.psm4.org

25GbE-10km Interoperation With PSM4



Compare worst-case Tx to worst-case Rx.

Tx: 25GbE-10km Rx: PSM4	25GbE SMF Tx Out (dBm)	PSM4 Channel Loss (dB)	PSM4 Rx In (dBm)	PSM4 Rx Spec (max)	Result
Tx OMA - TDP (min)	-5	3.3	-8.3	≥ -9.6	OK
Average Power (max)	2.5	0	2.5	≤ 2	Rx overload
Tx: PSM4 Rx: 25GbE-10km	PSM4 Tx Out (dBm)	PSM4 Channel Loss (dB)	25GbE SMF Rx In (dBm)	25GbE SMF Rx Spec (dBm)	Result
Tx OMA - TDP (min)	-7.25	3.3	-10.55	≥ -11.3	OK
Average Power (max)	2	0	2	≤ 2.5	OK

- Maximum power exceeds PSM4 Rx by 0.5 dBm.
- Otherwise, not compliant, but interoperable.

Summary

1. For 25GbE SMF specification, a possible approach is to adopt Tx characteristics of one lane of CWDM4.
 1. OMUX loss contribution becomes margin
 2. Need Rx characteristics consistent with 10km link power budget (9.3dB = 6.3dB (channel loss) + 3dB (TDP)).
2. Interoperability with PSM4 only limited by Rx P_{avg} MAX.
3. Purpose was only to survey and illustrate approach. Detailed discussion should be deferred to task force.
4. Would be good to explore:
 1. TDP
 2. ER
 3. Tx eye mask
 4. SRS