Towards an 800G-LR4 IMDD Specification Consensus - Nov. 2022 update

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Roberto Rodes, Coherent
Maxim Kuschnerov, Huawei
Frank Chang, Source Photonics
Rangchen (Ryan) Yu, SiFotonics
Mark Kimber, Semtech
Vipul Bhatt, Coherent
Xiang Liu, Huawei

Outline

- Introduction
- Update on MonteCarlo Analysis of FWM
- Tx Spec proposal for 800G-LR4
- Rx Spec proposal for 800G-LR4
- Link power budget
- Conclusion

Introduction

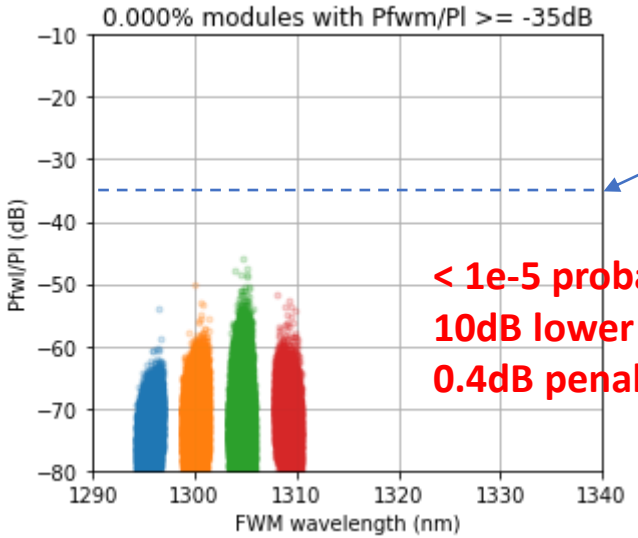
- This presentation expands the list of specs proposed in rodes_3df_01b_221012
  - Completes the same spec list used on previously published PMDs
- Consider these specs a good starting point, and expect further refinement based on contributions and discussions as the task force progresses

MonteCarlo Analysis on FWM Probability

Added power and extinction ratio distributions compared to previous results in rodes_3df_01b_221012

MC parameters:

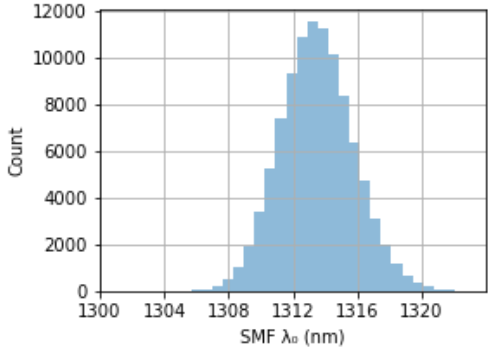
- 100,000 iterations
- Max fiber length: 10km
- Fiber ZDW based on realistic distribution rodes_3df_01b_221012
- OMA normal distribution centered at 4.4dBm minOMA@maxTDECQ
- ER uniform distribution 4 dB to 5.5dB
- Uniform wavelength distribution within passband for each channel



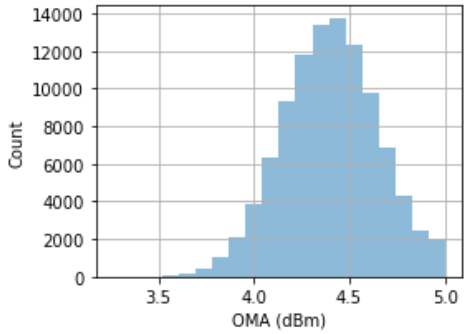
Limit for penalty < 0.4dB
kuschnerov_3df_01_221012

< 1e-5 probability @ -45dB
10dB lower than Xtalk limit for 0.4dB penalty

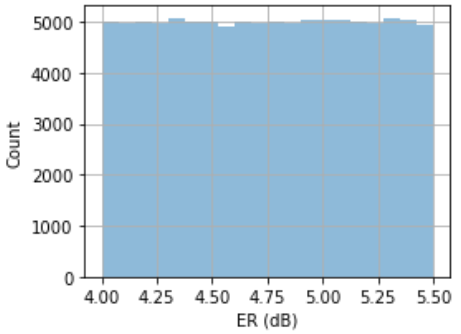
Fiber distribution



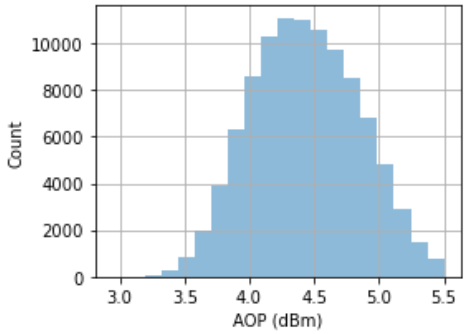
OMA distribution



ER distribution



AOP distribution



Tx Spec proposal

Following spec approach on rodes_3df_01b_221012:
TDECQmax = 3.9dB for full range
TDECQmax for limited dispersion = 3.2dB

FWM allocation of 0.7dB is probably still overly conservative

- <0.4dB may be achievable when using realistic fiber distribution

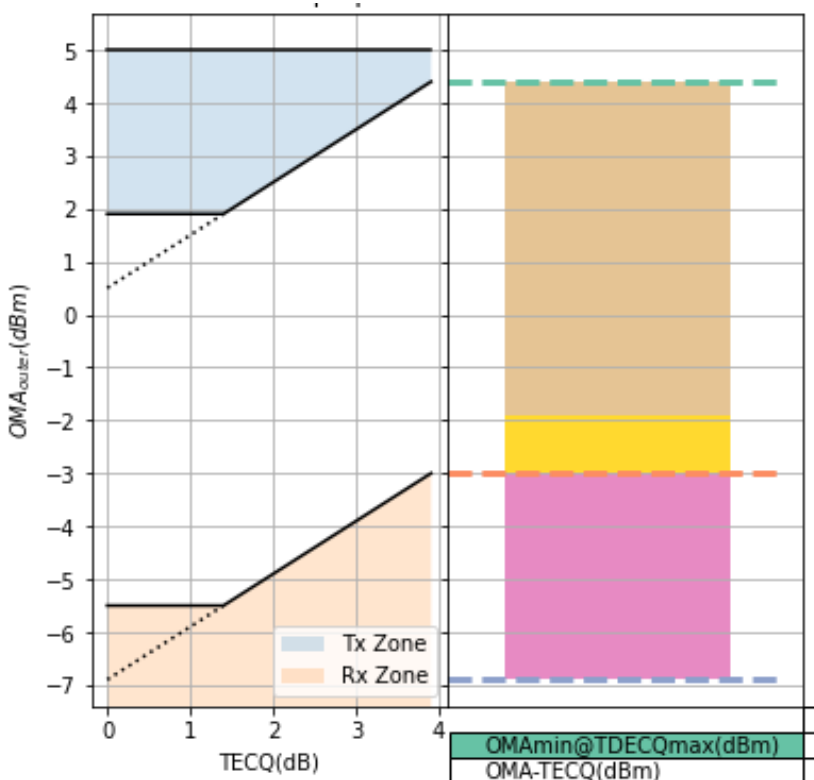
Description	800G-LR4 proposal	Unit
Signaling rate, each lane (range)	112.5 – 113.3	GBd
Modulation format	PAM4	
Lane wavelengths (range)	1294.6 to 1296.6 1299.1 to 1301.1 1303.6 to 1305.6 1308.1 to 1310.1	nm
Side-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	11.5	dBm
Average launch power, each lane (max)	5.5	dBm
Average launch power, each lane (min)	-0.9	dBm
Outer Optical Modulation Amplitude (OMAouter), each lane (max)	5	dBm
Outer Optical Modulation Amplitude (OMAouter), each lane (min) for TDECQ <1.4 dB for 1.4 dB ≤ TDECQ ≤ 3.9 dB	 1.9 0.5+TDECQ	 dBm dBm
Difference in launch power between any to lanes	3	dB
Transmitter and dispersion eye closure for PAM4 (TDECQ), each lane (max) -7ps/nm ≤ Dispersion ≤ 7 ps/nm -27ps/nm ≤ Dispersion ≤ 9 ps/nm	 3.2 3.9	 dB dB
Transmitter eye closure for PAM4 (TECQ), each lane (max)	3.2	dB
|TDECQ-TECQ| (max)	2.5	dB
Over/under-shoot (max)	22	%
Transmitter power excursion (max)	3.1	
Extinction ratio, each lane (min)	4	dB
Transmitter transition time (max)	13	ps
Average launch power of OFF transmitter, each lane (max)	-16	dBm
$RIN_{15.6}OMA$ (max)	-139	dBm
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance (max)	-26	dB

Rx Spec proposal

Rx sensitivity of -5.5dBm @ TDECQ = 1.4dB is achievable based simulation analysis:
rodes_3df_01b_221012
,and experimental data:
kuschnerov_3df_02_221012

Description	**800G-LR4 proposal**	**Unit**
Signaling rate, each lane (range)	112.5 – 113.3	GBd
Modulation format	PAM4	
Lane wavelengths (range)	1294.6 to 1296.6 1299.1 to 1301.1 1303.6 to 1305.6 1308.1 to 1310.1	nm
Damage threshold, each lane	6.5	dBm
Average receive power, each lane (max)	5.5	dBm
Average receive power, each lane (min)	-8	dBm
Receive power (OMAouter), each lane (max)	5	dBm
Difference in receive power between any two lanes (OMAouter) (max)	3.3	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMAouter), each lane (max) for TECQ <1.4 dB for 1.4 dB ≤ TECQ ≤ 3.9 dB	 -5.5 -6.9 + TECQ	 dBm dBm
Stressed receiver sensitivity (OMAouter), each lane (max)	-3	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ), lane under test	3.9	dB
OMAouter of each aggressor lane	1.3	dBm

Link Power Budget



	800G-LR4 IEEE proposal
OMAmin@TDECQmax(dBm)	4.4
OMA-TECQ(dBm)	0.5
RSnominal(dBm)	-6.9
Rx Sens (TECQ <= 1.4dB)	-5.5
SRS(dBm)	-3.0
PowerBudget	11.3
FiberLoss+connectors	6.3
AdditionalPenalties	1.1
AdditionalLossMargin	0.0
TDECQmax	3.9

Parameter	**800G-LR4 proposal**	**Unit**
Power budget (for maximum TDECQ)	11.3	dB
Operating Distance	10	km
Channel insertion loss	6.3	dB
Maximum discrete reflectance	-35	dB
Allocation for penalties (for maximum TDECQ) *	5	dB
Additional insertion loss allowed	0	dB

*DGD=0.7dB and MPI= 0.4dB *kuschnerov_3df_01a_221012*, *kuschnerov_3df_02_221012*

Conclusion

- Presented a complete set of specs for 800G-LR4
  - This is the same set of specs reliably used on 400G-FR4/LR4
  - Updated FWM penalty allocation
  - Many of the specs will be developed in sync with 800G-DR4/FR4
- This proposal is a good starting point, and we expect further refinement as the task force progresses

Thank you

Appendix

Maximum Individual Fiber PMD coefficient – cabled fiber

Information provided from [1]

- Analysis of fiber PMD and cabled fiber PMD
- AllWave fiber is G.652D with 12 km loose tube cables (single section)
- Distribution shape is different as assumed in the 100G LR1 DGD specification derivation (see page 3)
- Overall statistics show that the distributions of spooled and cabled fibers are very similar

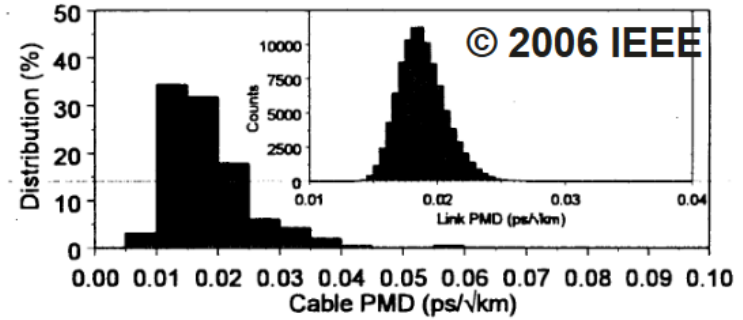


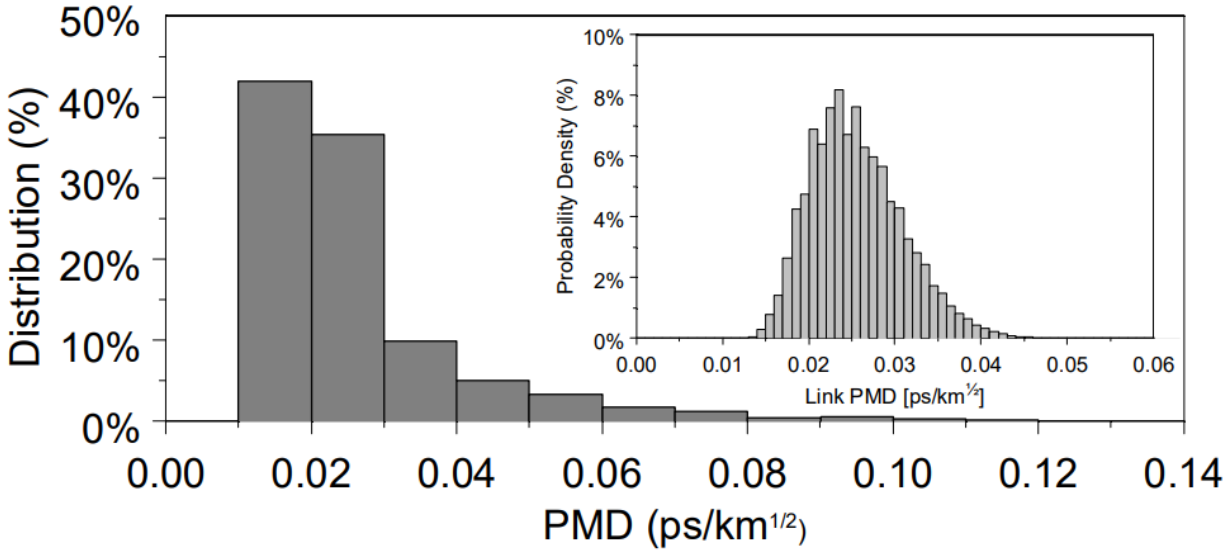
Figure 7. The PMD coefficient distribution for 264 AllWave® fibres in 12 km loose tube cable. The inset shows the PMD link distribution. The resulting LDV is 0.028 ps/√km.

[1] Tommy Geisler, "Low PMD Transmission Fibers", European Conference on Optical Communications (ECOC) Cannes, France, Sep 2006.
DOI: 10.1109/ECOC.2006.4800871 © IEEE

FWM penalty assessment

The PMD coefficient distribution for 1653 G.652D fibers in 12 km loose tube cable. The inset shows the link PMD distribution.

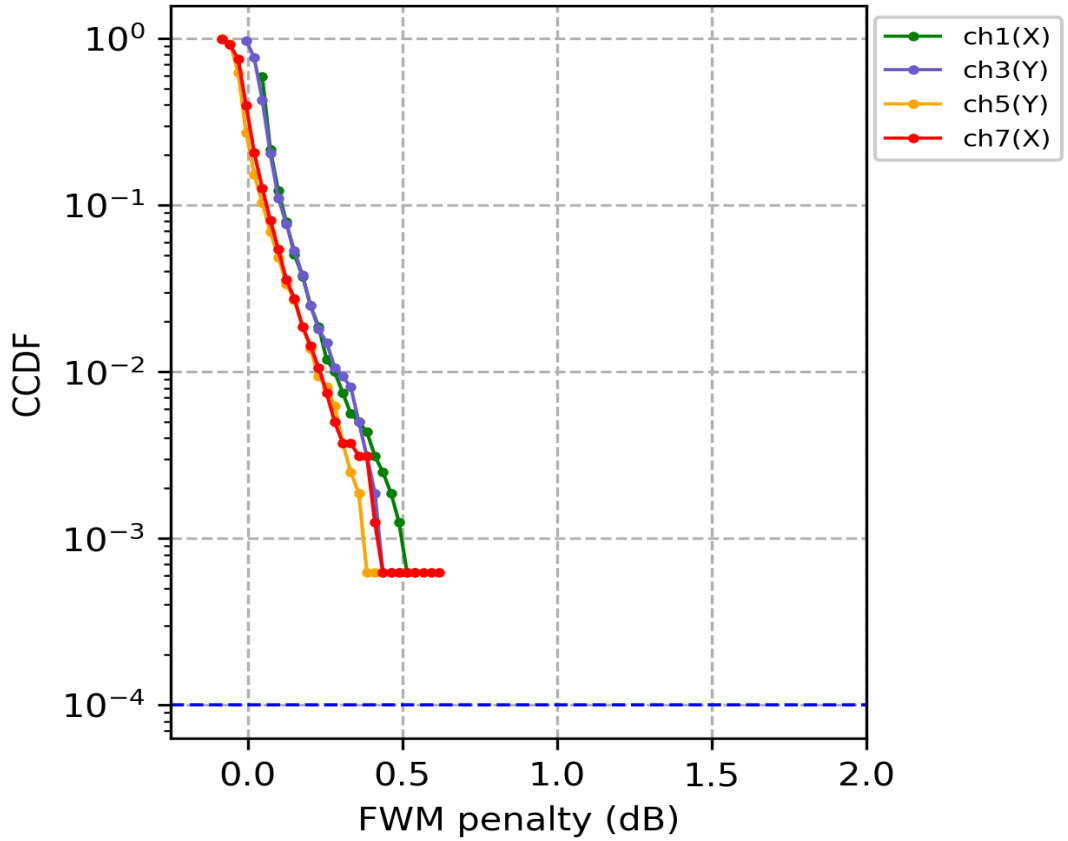
The resulting link design value (LDV) **is 0.05 ps/√km.**



Reference: T. Geisler, "Low PMD transmission fibers and cables," Proc. SPIE 6781, Passive Components and Fiber-based Devices IV, 67811U (21 November 2007); doi: 10.1117/12.745256. ttps://ui.adsabs.harvard.edu/abs/2007SPIE.6781E..1UG/abstract

Simulation conditions

1600 runs with PMD = 0.05 ps/sqrt(km), ER=4dB, OMA=5dBm, AOP=5.65dBm/channel



- Even under the worst-case alignment of ZDW and laser frequencies, the FWM-induced "outage" is $<10^{-3}$.
- Thus, the FWM-induced overall outage probability can be $\sim 3\times10^{-6}$, which is reasonably low (liu_3df_01a_221012).