



400GBase-LR8: A Proposal for 10 km Objective Using 50 Gb/s PAM4 Signaling

Ali Ghiasi – Ghiasi Quantum LLC

IEEE 802.3bs Task Force – Berlin March 2015

List of supporters

- ▶ Mike Furlong – Clariphy
- ▶ Sudeep Bhoja – Inphi
- ▶ Vipul Bhatt – Inphi
- ▶ Vasu Parthasarathy – Broadcom
- ▶ Dan Dove – Dove Networking

Addressing Big Ticketed Items (Page 13)

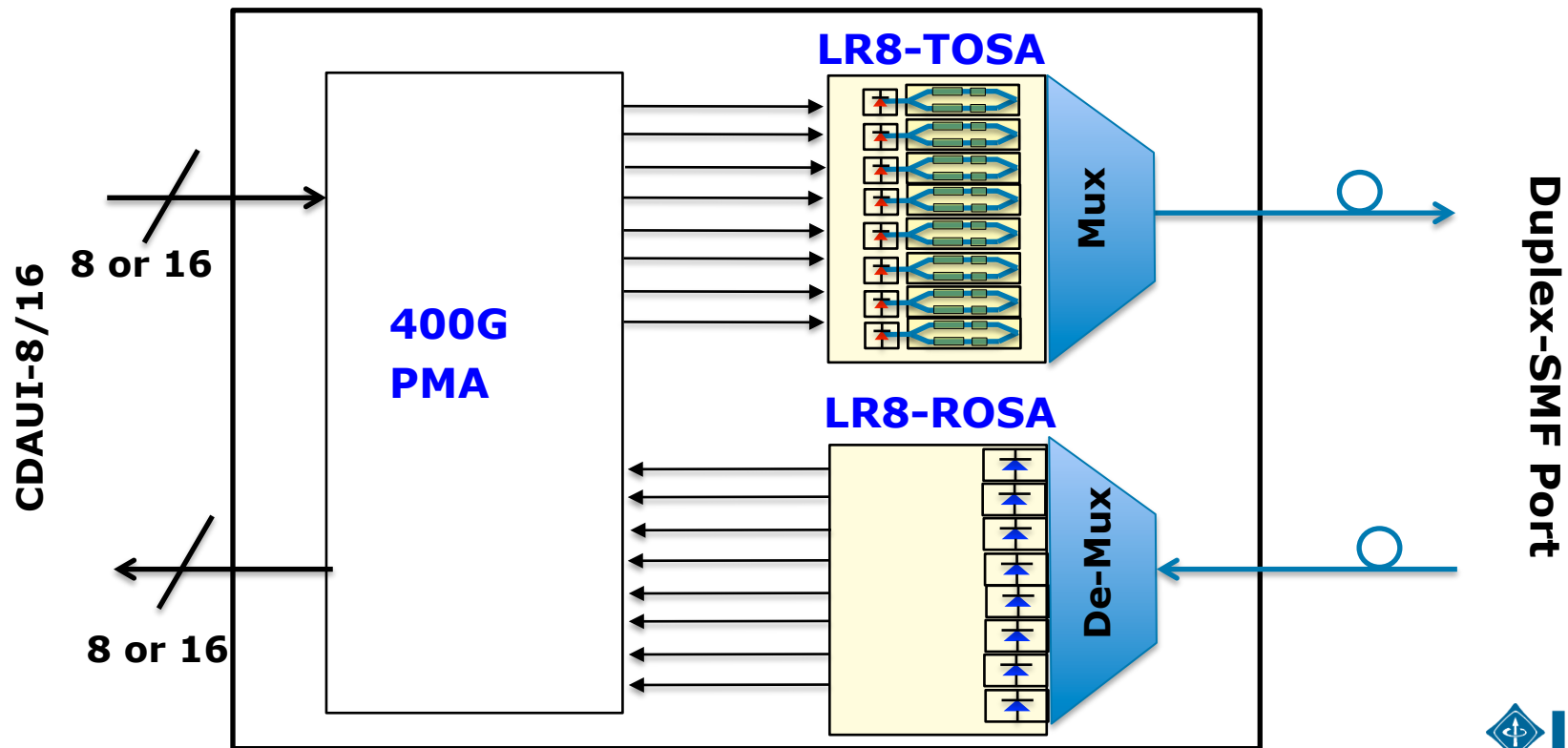
- ▶ Enhancement to Cole_3bs_02_0115.pdf (PAM4)
- ▶ Addressing following actions:
 - Evaluate Coupling between electrical and optical interfaces
 - RX Technical feasibility
 - Dispersion penalty worst case (in SMF ad hoc)
 - TDP
 - MPI
 - RX sensitivity.

Merits of 400Gbase-LR8 Based on PAM4

- ▶ 10 km duplex is required by 15% of router applications and can't be satisfied by 2 km
 - http://www.ieee802.org/3/bs/public/14_07/huang_3bs_01_0714.pdf
- ▶ Supports broad set PMD implementation
 - Supports DML, EML, and Silicon photonics
- ▶ Leverages broadest availability of PMA/PHY
 - More than 10 companies (PHY, ASIC, IP provider) either have or developing 50 Gb/s PAM4 solutions based on anticipated future 50 Gb/s PAM4 backplane and Cu cabling.

400Base-LR8 Implementation

- Supports broad set of implementations based on DML, EA, and Silicon Photonics



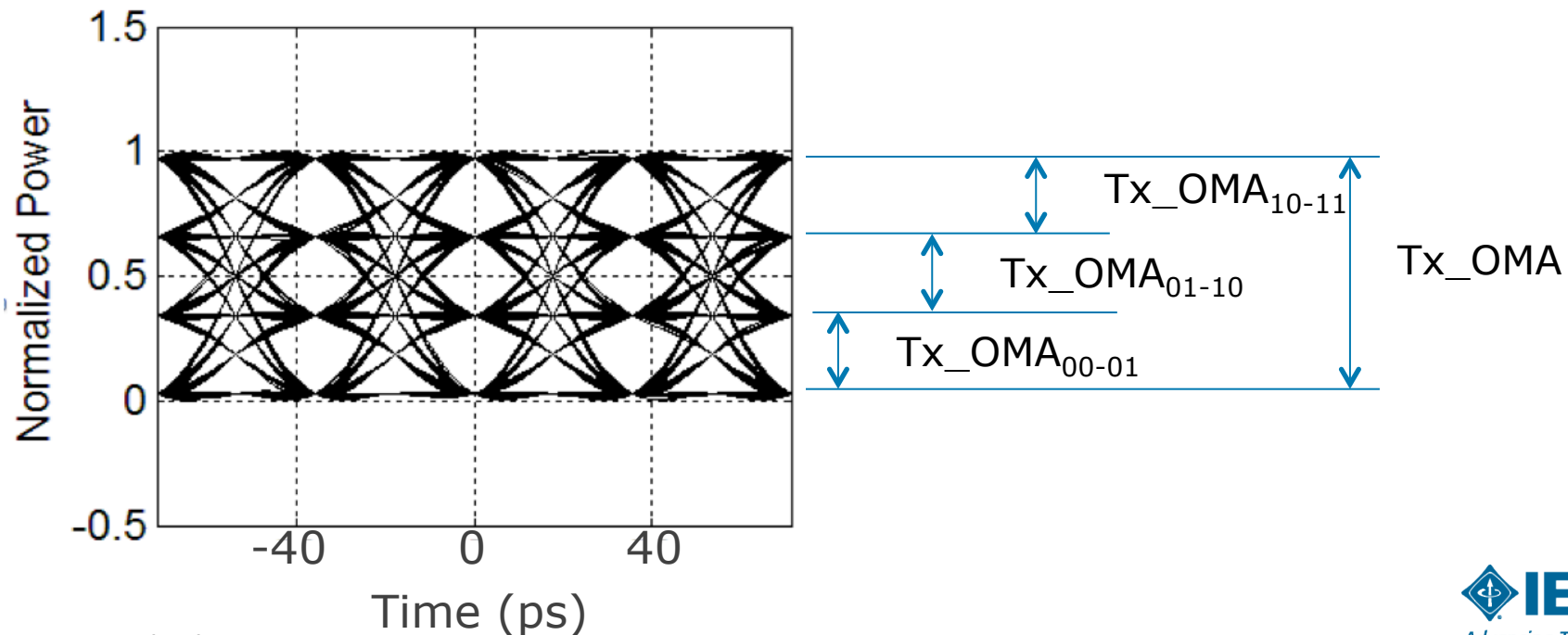
50 Gb/s PAM4 10 km Transmit Characteristics

Parameters	Min	Nominal	Max	Unit
Signaling Rate, each lane		26.56±100 PPM		GBd
Pre-FEC Operating BER		3.0E-4		
Average launch power each	-3.2		1.5	dBm
OMA ₀₀₋₁₁ , each lane	-0.2		1.5	dBm
TDP each lane			2	dB
Launch power OMA ₀₀₋₁₁ -TDP	-1.2			dBm
Launch power OMA ₀₀₋₀₁ , OMA ₀₁₋₁₀ , OMA ₀₀₋₁₁	TBD			dBm
RIN			-140	dB/Hz
Extinction ratio	4.5			dB
Transmitter 3 dB bandwidth	21			GHz
Transmitter reflectance			-20	dB
Optical return loss tolerance	26			dB



Transmitter Specifications

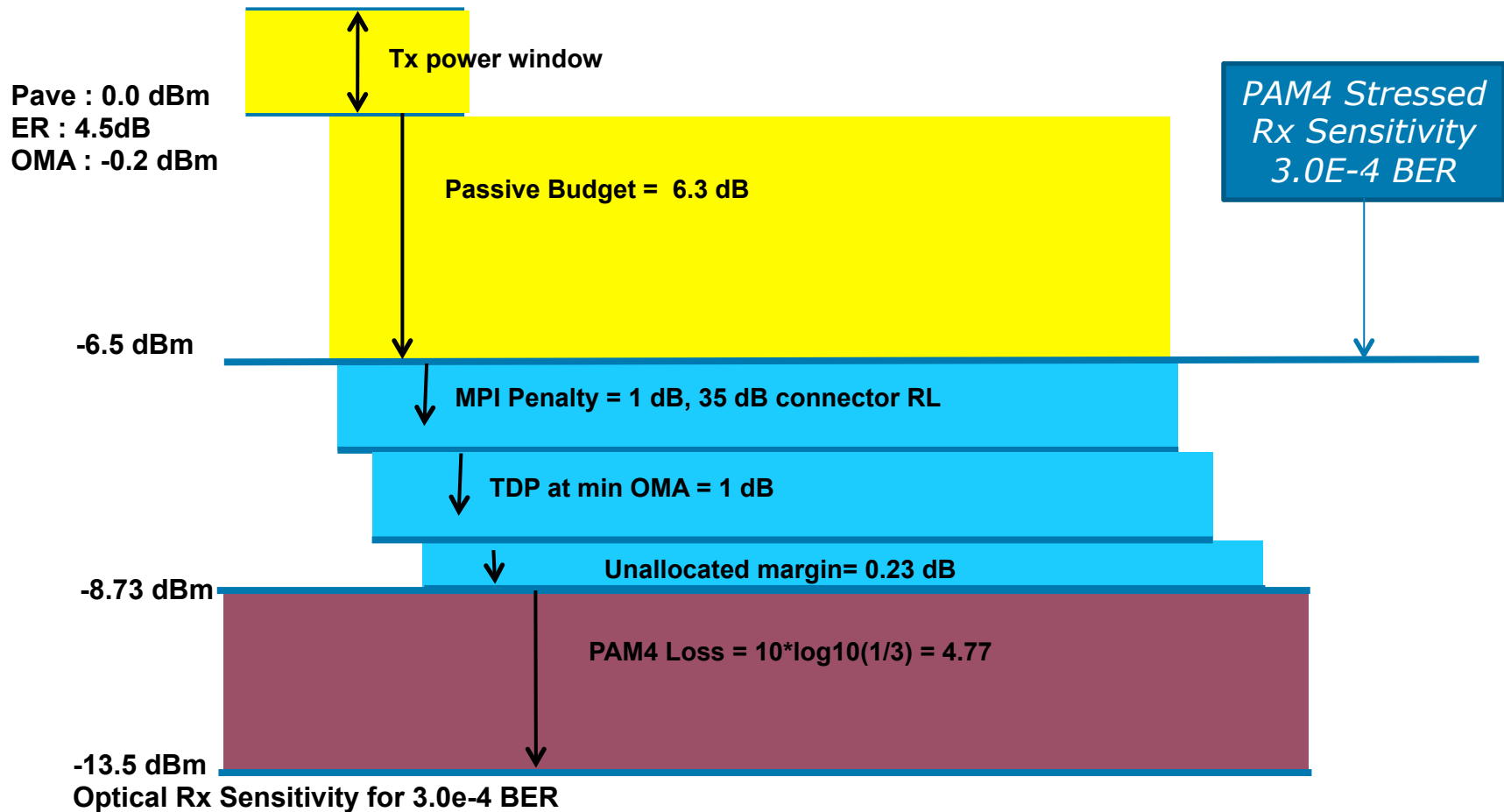
- ▶ ER measured between level 00 and 11
- ▶ Sensitivity and link budget based on meeting all 3 inner eyes
 - TX_OMA_{00-01} , TX_OMA_{01-10} , TX_OMA_{01-11} .



50 Gb/s PAM4 10 km Receive Characteristics

Parameters	Min	Nominal	Max	Unit
Signaling Rate, each lane		26.56±100 PPM		GBd
Pre-FEC Operating BER		3.0E-4		
Post-FEC Operating BER		1E-13		
Receiver sensitivity AOP	-8.53			dBm
Receiver sensitivity OMA_{00-11} , each lane	-8.73			dBm
Receiver sensitivity OMA_{00-01} , OMA_{01-10} , OMA_{10-11} each lane	-13.5			dBm
Receiver 3 dB upper cutoff frequency	21			GHz
Receive reflectance			-26	dB

400Gbase-LR8 Link Budget



400Gbase-LR8 Fiber and Connector Requirements

- ▶ MPI penalty calculated assuming 6 mid-span connectors.

Parameters	Value	Unit
Nominal fiber specifications wavelength	1310	nm
Cabled optical fiber attenuation (max)	0.43 ^I or 0.5 ^{II}	dB/km
Zero dispersion wavelength (λ_0)	$1300 \leq \lambda_0 \leq 1324$	nm
Dispersion slope S_0 (max)	0.093	Ps/nm ² .km
Number of connectors	6	
Connector return loss (min) ^{III}	35	dB

I. The 0.43 dB/km at 1295 nm attenuation for optical fiber cables is derived from Appendix I of ITU-T G.695.

II. Attenuation per ANSI/TIA/EIA 568-B3-2000 outside plant cabling.

III. Connector discrete reflectance per ISO/IEC11801.

50 Gb/s PAM4 Link Budget

Parameters	Nominal	Unit
Passive Loss	6.3	dB
MPI	1.0	dB
TDP at minimum OMA (max) ^I	1.0	dB
Unallocated margin	0.23	dB
Total Link Budget	8.53	dB

I. TDP can increase to 2.0 dB if OMA is increases by 1.0 dB.

400GBase-LR8 LAN-WDM Lane Assignment

Lane	Center Frequency (THz)	Center Wavelength (nm)	Wavelength Range (nm)
L0	235.4	1273.55	1272.55 to 1274.54
L1	234.6	1277.89	1276.89 to 1278.89
L2	233.8	1282.26	1281.25 to 1283.28
L3	233.0	1286.66	1285.65 to 1287.69
L4	231.4	1295.56	1294.53 to 1296.59
L5	230.6	1300.05	1299.02 to 1301.09
L6	229.8	1304.58	1303.54 to 1305.63
L7	229.0	1309.14	1308.09 to 1310.19

Area of Further Study

- ▶ Current MPI penalty is very conservative based on worst case lossless interferometric penalty which is too conservative
 - Based on the outcome of MPI study group potentially connector return loss could be relaxed to 26 dB or MPI penalty reduced
 - 26 dB connector could also be supported by trading loss with MPI penalty
- ▶ Initial study indicate -13.5 dB OMA receiver sensitivity is feasible
 - Also considering inner eye opening as better measure of sensitivity requirement.

Thank You!