Thoughts on the baseline of 200G/lane single wavelength/PSM optical PMDs

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Introduction

- Let's put the debate on FEC modes aside for a moment. Look at the baselines for 200G/lane single wavelength/PSM optical PMDs which include 200GBASE-DR1, 200GBASE-FR1, 400GBASE-DR2, 400GBASE-DR2-2, 800GBASE-DR4, 800GBASE-DR4-2, 1.6TBASE-DR8, 1.6TBASE-DR8-2.
  - Brian has brought a series of baseline proposals on these PMDs, the latest version being welch_3dj_03b_2309
  - Guangcan provided a different approach on the baselines targeting the same PMDs, shown in mi_3df_01a_2211
- The major differences or TBDs are
  1. Specs for Tx output power and Rx sensitivity
  2. TECQ/TDECQ
  3. Ref. Rx definition

This contribution focuses on the discussion of the first item under FECi mode.

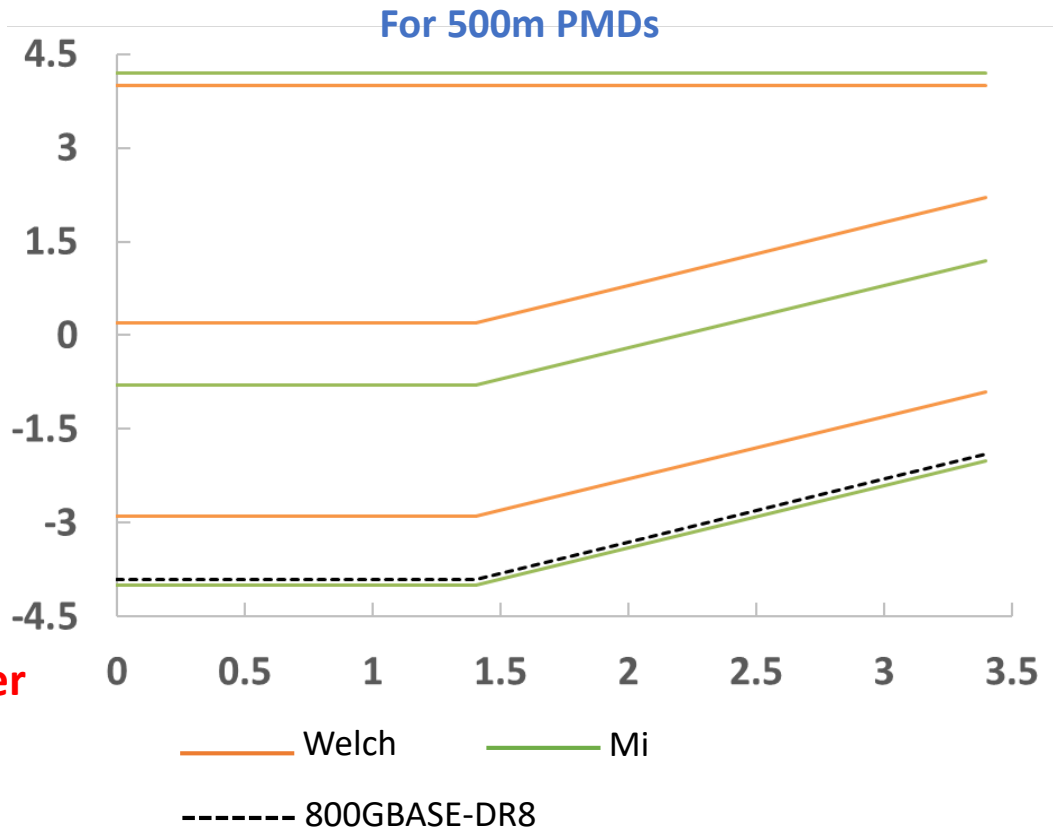
Link Budget Needs to Balance the Burden on Tx & Rx

- **Two baseline proposals represents two directions to close the link**

		400GBASE-DR2 800GBASE-DR4 1.6TBASE-DR4 200GBASE-DR1		800G-DR8	
		Mi-2211	Welch-2309	802. 3df	
Transmitter					
Tx $OMA_{outer\ min}$	TDECQ<1.4dB	-0.8	0.2	-0.8	dBm
	1.4dB≤TDECQ≤3.4dB	-2.2+TDECQ	-1.2+TDECQ	-2.2+TDECQ	dBm
Receiver					
OMA_{outer} Receiver Sensitivity	TECQ<1.4dB	-4	-2.9	-3.9	dBm
	1.4dB≤TECQ≤3.4dB	-5.4+TECQ	-4.3+TECQ	-5.3+TECQ	dBm

Better Rx sensitivity

Higher Tx Power



The question becomes philosophical

Can 200G/lane Rx be built with enough margin to allow the SAME Tx output power as in 100G/lane?

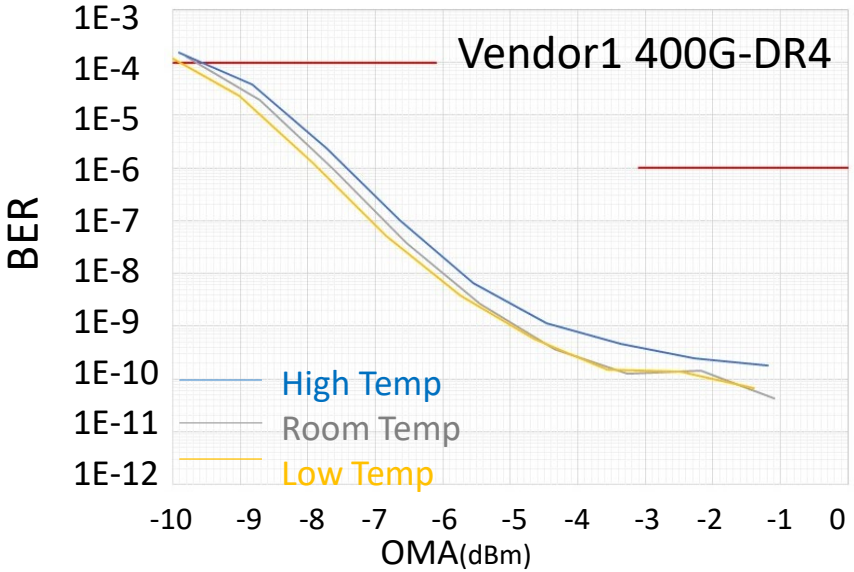
Considerations on Transmitter Side

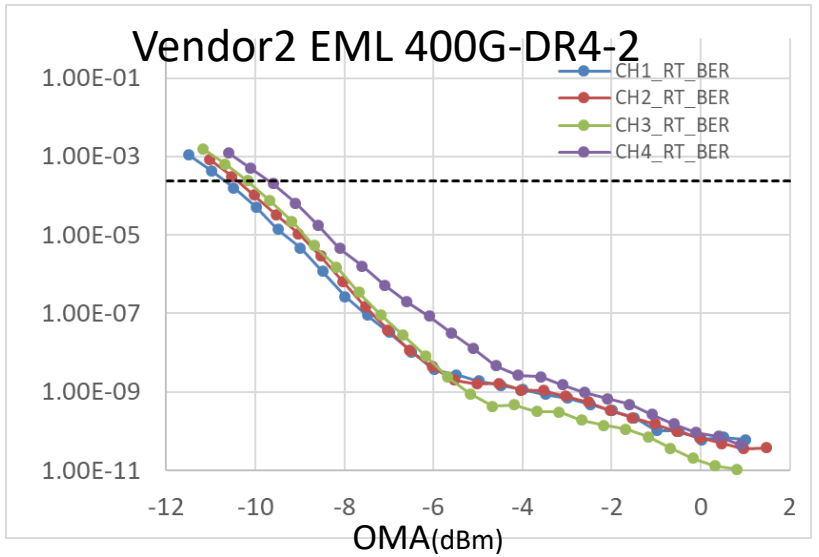
- Module vendors always have more challenges at Tx side with lower yield
  - Raising Tx power could reduce the transmitter yield
  - PSM type optical modules have always been very cost-sensitive
- Raising Tx output power will lead to higher laser power
  - Assuming 30mW/channel laser power is needed, additional 1 dB output power means 6 mW more power from the laser. For 8 lasers with ~16% (10%) WPE, that would be 300 mW (480 mW) more without considering heat dissipation.
  - Independent of the Tx technology used.
  - Setting high Tx output power will lock in higher module power.
- Raising Tx power will bring more challenges in thermal management & laser reliability
  - This is particularly challenging for SiPh and TFLN implementations, where high power CW lasers with 1:2 or higher ratio power splitting is typically used.

Not to raise the Tx power benefits the chip/module suppliers and system users

Considerations on Receiver Side

- Rx Performance of 100G/lane modules today

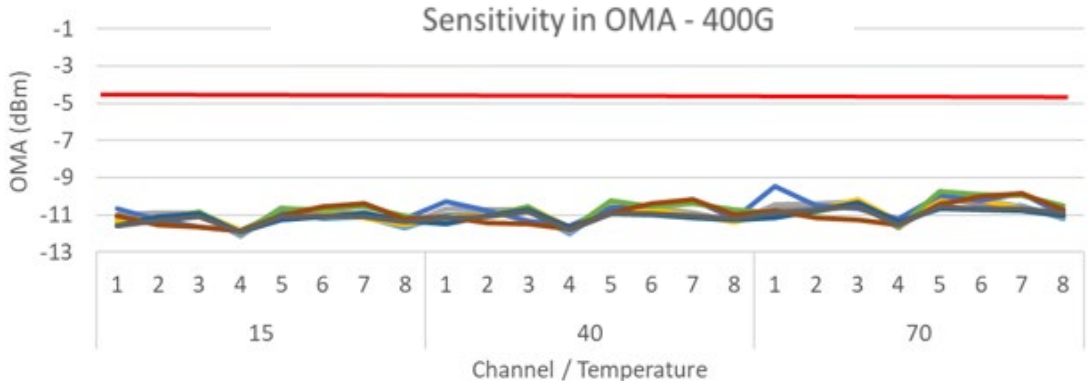


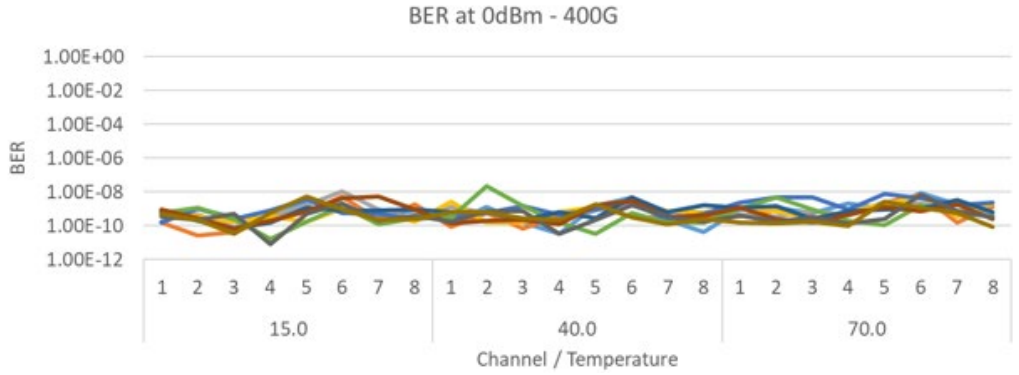


- > 5 dB margin in receiver sensitivity and
- BER noise floor can be 5 decades below 2E-4.

More than sufficient margin

Vendor4 SiPh 800G(2x400G)





- If an additional ~2 dB is needed in Rx sensitivity to scale from 100G/lane to 200G/lane, keeping the Tx output power as in 100G/lane link should still have margin for 200G/lane.

Where to land for TECQ/TDECQ max

Evolution from 50G to 100G, TECQ loosen not tighten.

	50G/lane	100G/lane	200G/lane
Signaling rate	26.5625	53.125	113.4375
FEC	KP4	KP4	KP4+inner FEC(128, 120)
BER limit	2.4e-4	2.4e-4	4.85e-3
TECQ/TDECQ max (only considering <2km)	3.1-3.4 dB	3.4dB	(tentatively 3.4dB) ?
Ref. Rx	5 FFE	5 FFE	FFE ?

more than doubled signaling rate

Small CD range-3.2 ~ 3.7 ps/nm
Nonlinearity more of a problem

There has been some discussions on Ref. Rx so far in the Task force

- mi_3dj_optx_01_230427 provided simulation on TECQ considering different chirp condition of an EML device, suggesting no less than 9 taps of FFE used in Ref. Rx.
- rodes_3dj_02b_2305 provided detailed simulation analysis based on EML, showing the need of >15 taps.
- liu_3dj_optx_01a_231019 showed measured TECQ vs number of FFE taps in Ref. Rx, showing a tipping point beyond 9 taps. First Measured Data!

Need more work to build consensus.

Updated Baseline Proposal (from mi_3df_01a_2211)

Proposed Transmitter Specifications

PMD		400GBASE-DR2 800GBASE-DR4 1.6TBASE-DR8 200GBASE-DR1	400GBASE-DR2-2 800GBASE-DR4-2 1.6TBASE-DR8-2 200GBASE-FR1	Unit
Baud rate		113.4375 +-50ppm		GBd
Modulation Format		PAM4		-
Wavelength Range		1304.5 to 1317.5		nm
Transmitter				
SMSR (min.)		30	30	dB
P_ave, each lane (max.)		4	4	dBm
P_ave, each lane (min.) *		-2.9		dBm
OMA_outer (max.)		4.2	4.2	dBm
$OMA_{outer\ min}$	TDECQ < 1.4dB	-0.8	- 0.1	dBm
	1.4dB≤TDECQ≤3.4dB	-2.2+TDECQ	-1.5+TDECQ	dBm
ER, each lane (min.)		3.5	3.5	dB
TDECQ (max.)+		3.4	3.4	
TECQ (max.)		same as TDECQ		
|TDECQ-TECQ| (max.)		TBD	TBD	dB
over/under-shoot (max.)		22	22	%
Optical Return loss tolerance (max.)		21.4 15.5(for 200G-DR1)	21.4 17.1(for 200G-FR1)	dB
Transmitter reflectance(max.)		-26	-26	dB
Transition time (max.)		8	8	ps
P_ave off, each lane (max.)		-15	-15	dBm
RIN_xOMA (max.)		-139	-139	dB/Hz

Proposed Receiver Specifications

PMD		400GBASE-DR2 800GBASE-DR4 1.6TBASE-DR8 200GBASE-DR1	400GBASE-DR2-2 800GBASE-DR4-2 1.6TBASE-DR8-2 200GBASE-FR1	Unit
Damage threshold, each lane		5	5	dBm
P_ave, each lane (max.)		4	4	dBm
P_ave, each lane (min.)		-5.9	-6.9	dBm
OMA_{outer}, each lane (max.)		4.2	4.2	dBm
Receiver Reflectance (max)		-26	-26	dB
Receiver sensitivity, each lane (max.)	TECQ < 1.4 dB	-4.0	-4.5	dBm
	1.4dB ≤TECQ ≤3.4 dB	-5.4+TECQ	-5.9+TECQ	dBm
Stressed receiver sensitivity OMA_{outer}, each lane		-2.1	-2.2	dBm
Stressed RS test condition				
SECQ		3.4	3.4	dB
OMA_outer, each aggressor lane (max.)#		4.2	4.2	dBm

Proposed Link Budget

Link Power budget for Max. TDECQ	6.6	7.8	dB
Operating distance	500	2000	m
TDECQ	3.4	3.4	dB
Allocation of Penalties (MPI+DGD)	0.2	0.4	dB
Channel Loss	3	4	dB
Discrete Reflectance (max)	35	35	dB

*: P_ave min of -2.9dBm corresponds to OMAouter_min of -0.8dB with ER of 10dB, and OMAouter_min of -0.1dB with ER of 16dB (consistent with 802.3df D3.1)

+: Ref. Rx: FFE TBD with SER @ 9.7e-3

#: No need of aggressor lane for 200GBASE-DR1 and 200GBASE-FR1

Summary

- Development of 200G/lane optical modules are underway. Baseline specs for 200G/lane PMDs, especially PSM types, are needed to provide the industry with needed guidance.
- Some numbers are solid
  - FECi, BER limit, signaling rate
- Some show good consensus
  - RIN, overshoot, power max, overload etc..
- It is suggested to start making decisions on better direction for closing the optical links: To Raise Tx Power Or To Build Good Rx.
- For 200G/lane DR and DR-2 PMDs, we suggest to maintain the Tx Power the same or similar to that of 100G/lane PMDs, to save module power, as well as best leverage the existing supply chain of components.
- Consensus build on TECQ and Ref. Rx requires further analysis and data.

Backup slides

More data on 100G/lane optics