Towards an 800G-LR4 IMDD specification consensus

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Outline

- The goal of this presentation is to work towards a consensus on using PAM4 IMDD for 800G-LR4
- Multiple IEEE presentations have shown the importance of managing four-wave mixing (FWM) and chromatic dispersion (CD) on 10km links
- This presentation updates and compares 2 approaches presented in rodes_3df_01a_220329 and yu_3df_01a_220329 to manage FWM and CD
- There are multiple paths of supporting 800G over 10km links with IMDD
- An IMDD LR4 solution will benefit from the re-use of 500m and 2km reach solutions (components, technology, supply chain and testing)

How to manage FWM?

On FWM we need to consider both:

- Magnitude of the FWM generation under worst-case conditions
- Probability of occurrence

johnson_3df_optx_01_220414

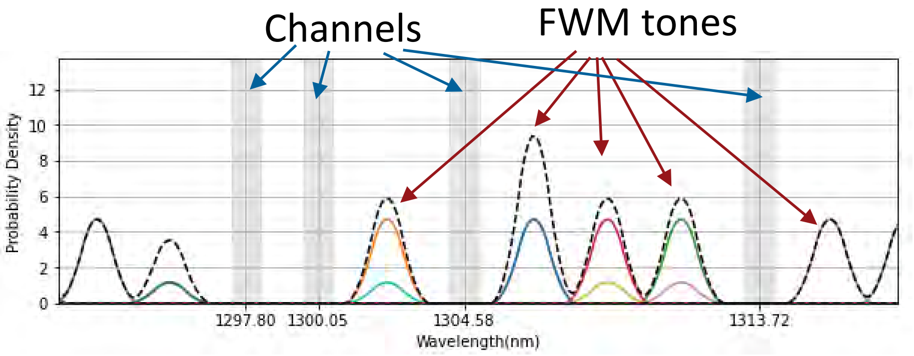
Two Proposed Solutions:

- Option A: Unequal spacing -> Zero probability of occurrence (rodes_3df_01a_220329)
- Option B: Low Tx power -> Small magnitude under worst-case conditions (yu_3df_01a_220329)

Both solutions can eliminate FWM concern

Option A: Unequal spacing

- Based on proposal in rodes_3df_01a_220329
- Unequal channel spacing guarantees FWM tones to fall outside the channel passband
- FWM does not depend on Tx power, it can use Tx&Rx OMA levels similar than other FR4/LR4 specs
- Updated spacing: 400, 800 and 1600GHz
  - Uses channels from CW-WDM MSA
  - Reduce maximum positive dispersion. More friendly for EMLs
  - Requires +/-0.45nm laser accuracy



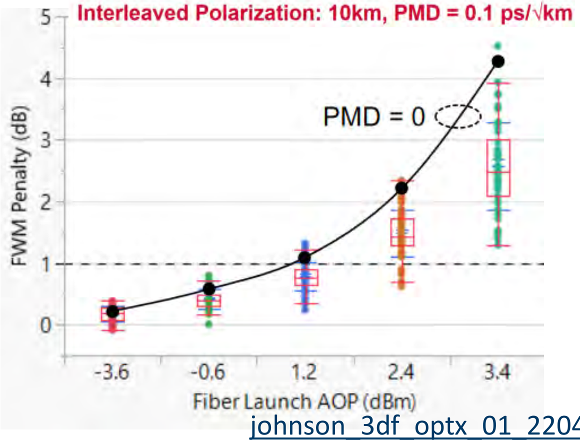
CW-WDM MSA Technical Specifications Rev 1.0 Table 2-3

1293.32	231.8
1295.56	231.4
1297.80	231.0
1300.05	230.6
1302.31	230.2
1304.58	229.8
1306.85	229.4
1309.14	229.0
1311.43	228.6
1313.73	228.2
1316.03	227.8
1318.35	227.4

https://cw-wdm.org/?wpdmdl=2092

Option B: Low Tx Power

- Yu et al Proposed reduced Tx OMA power with polarization to mitigate against FWM penalties (yu_3df_01a_220329.pdf)
  - Tx OMAouter max: + 1.0 dBm
  - Tx OMAouter min:
    - -2.0dBm with TECQ < 1.4dB
    - -3.4dBm+TECQ with TDECQ>1.4dB
- Updated spacing to 800GHz:
  - Channel plan is LWDM with +400GHz off-set
  - Relaxes laser accuracy requirement to +/-1nm
- Allows for lower CD by reducing spacing to 400GHz
- Rx Sensitivity requirement:
  - -9.8dBm with TECQ < 1.4dB
  - -11.2dBm+TECQ with TECQ/TDECQ>1.4dB



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Option B: Low Tx Power

- Yu et al Discussed APD receiver option to improve sensitivity (yu_3df_01a_220329)
  - 106GBaud Ge/Si APD potentially may achieve sensitivity ~ -12.5dbm @2E-3
- Lin et al discussed SOA+ PIN receiver option to higher sensitivity receivers (lin_3df_01_220609)
  - Demonstrated Rx sensitivity:
    - OMA=-11.6 dBm (ROP=-11.0 dBm) @ 2e-3
    - OMA=-12.1 dBm (ROP=-11.5 dBm) @ 4e-3
  - Possible to improve sensitivity further with integrated TIA

Chromatic Dispersion Penalty Simulations

Option A:

Min disp = -25.3

Max disp= 12.8

Option B:

Min disp = -25.8

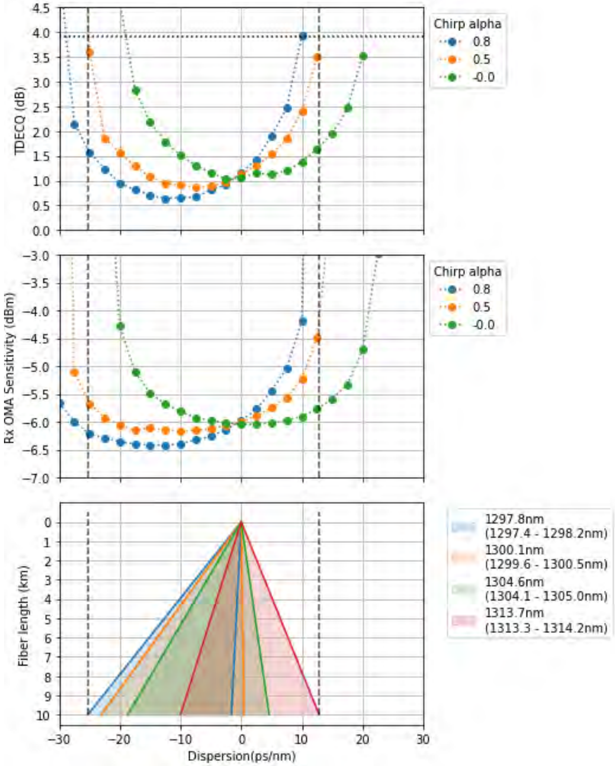
Max disp= 11.3

TDECQ Ref Rx: 21-tap FFE TDECQ

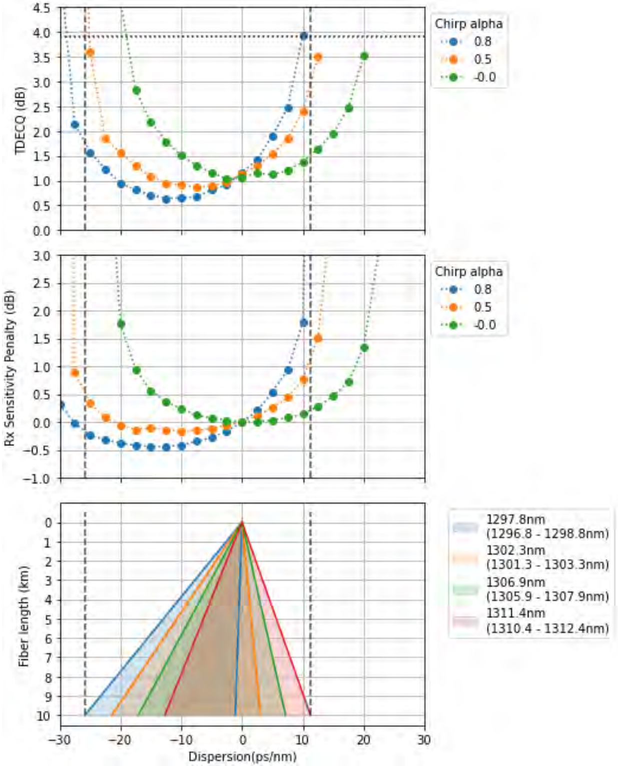
Rx DSP: FFE+ 1-tap PR MLSD

Pre-FEC BER 4.85e-3 (patra_3df_01_2207)

Option A: Unequal spacing

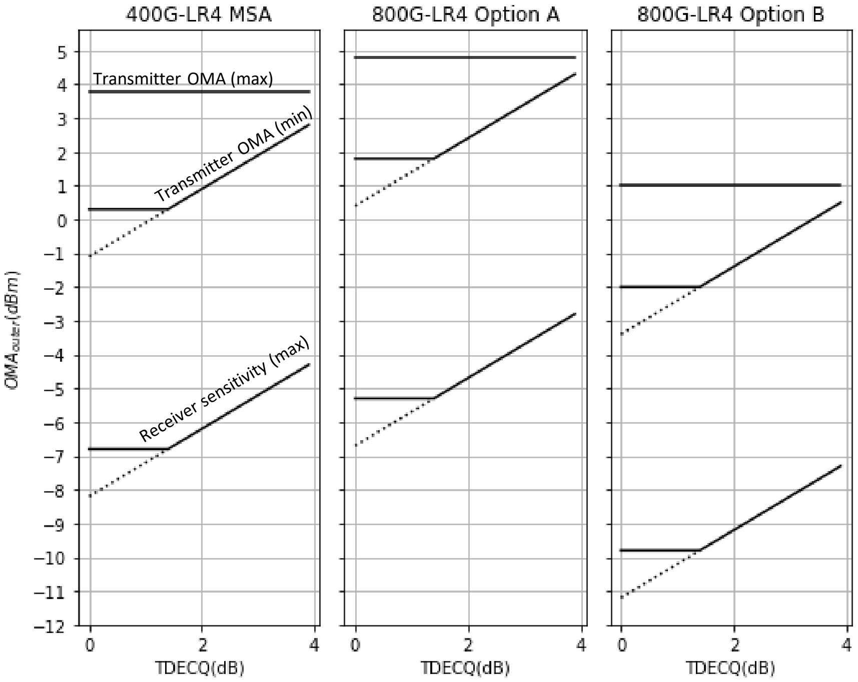


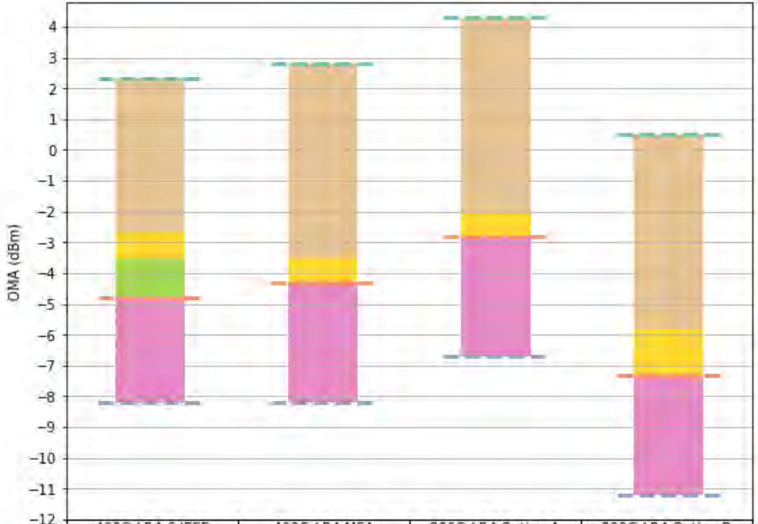
Option B: Low Tx Power



Chromatic dispersion range is within DSP equalization capability

Tx, Rx Specs and Power Budget Comparison





	400G-LR4-6 IEEE	400G-LR4 MSA	800G-LR4 Option A	800G-LR4 Option B
OMAmin@TDECQmax(dBm)	2.3	2.8	4.3	0.5
OMA-TDECQ(dBm)	-1.1	-1.1	0.4	-3.4
RSnominal(dBm)	-8.2	-8.2	-6.7	-11.2
Rx Sens (TDECQ <= 1.4dB)	-6.8	-6.8	-5.3	-9.8
SRS(dBm)	-4.8	-4.3	-2.8	-7.3
PowerBudget	10.5	11.0	11.0	11.7
FiberLoss+connectors	5.0	6.3	6.3	6.3
AdditionalPenalties	0.8	0.8	0.8	1.5
AdditionalLossMargin	1.3	0.0	0.0	-0.0
TDECQmax	3.4	3.9	3.9	3.9

Option A relaxes Rx sensitivity spec by 1.5dB going from 100G/lane to 200G/lane

Option B limits Tx OMA max to 1dBm to bound FWM penalty

Comparison of Proposals

	Option A: Unequal Spacing	Option B: Low Tx Power
Channel Plan	1297.8 nm 1300.1 nm 1304.6 nm 1313.7 nm	1297.8 nm 1302.3 nm 1306.9 nm 1311.4 nm
Channel Passband	+/-0.45 nm	+/-1 nm
Channel Polarization Interleaved	Not required	Interleaved at launch
Dispersion range	-25.3 to +12.8 ps/nm	-25.8 to +11.3 ps/nm
Tx OMA min	1.8 dBm	-2 dBm
FWM Penalty	0 dB	1.3 dB
Rx OMA sensitivity (TDECQ<1.4dB)	-5.3dBm	-9.8dBm

Conclusion

- 800G-LR4 can be supported with PAM4 and direct detection with at least two strong options (with other effective FWM suppression options still possible)
- We presented pros and cons for each option and compared them to each other
- Both options use a narrower wavelength plan to limit chromatic dispersion
- Each option uses a different method to manage four-wave mixing:
  - Option A uses unequal channel spacing
  - Option B uses low Tx optical power and interleaved polarization
- Use of direct-detect for 10 km reach will re-use and leverage a huge base of technologies and components deployed for 500 m and 2 km reach solutions

Thank you