Refined 800G-LR4 IMDD optical specifications

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Outline

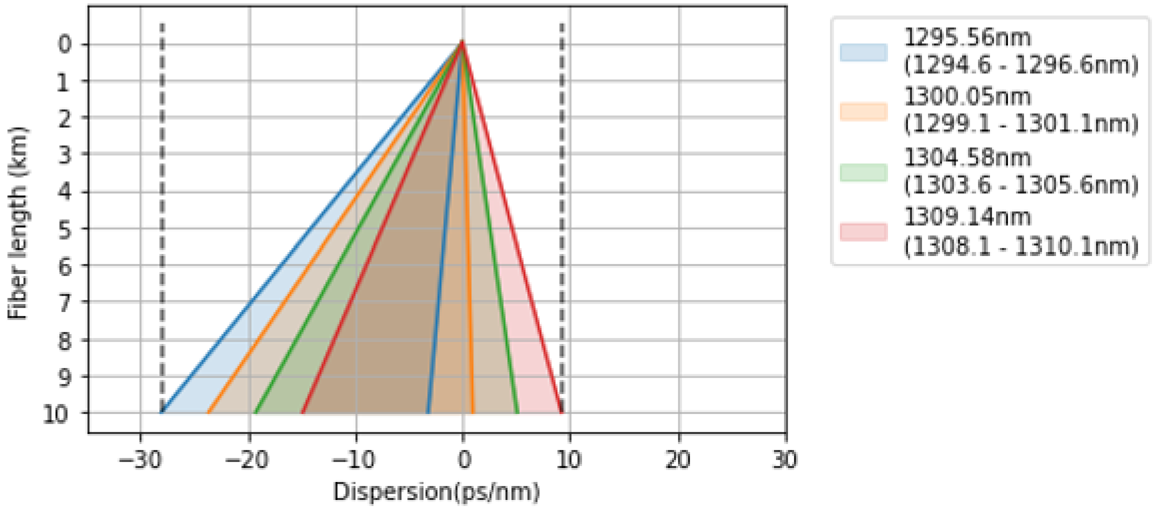
- Introduction
- Wavelength Plan
- Chromatic Dispersion
- Four-wave mixing
- Combining FWM and dispersion penalties
- Rx Sensitivity
- Power Budget, Tx and Rx specs
- Conclusion

Introduction

- The goal of this presentation is to consolidate in a single proposal a solution for 800G-LR4 with PAM4 and direct-detection
- This is a starting point, and we expect further refinement based on contributions and discussions as the task force progresses

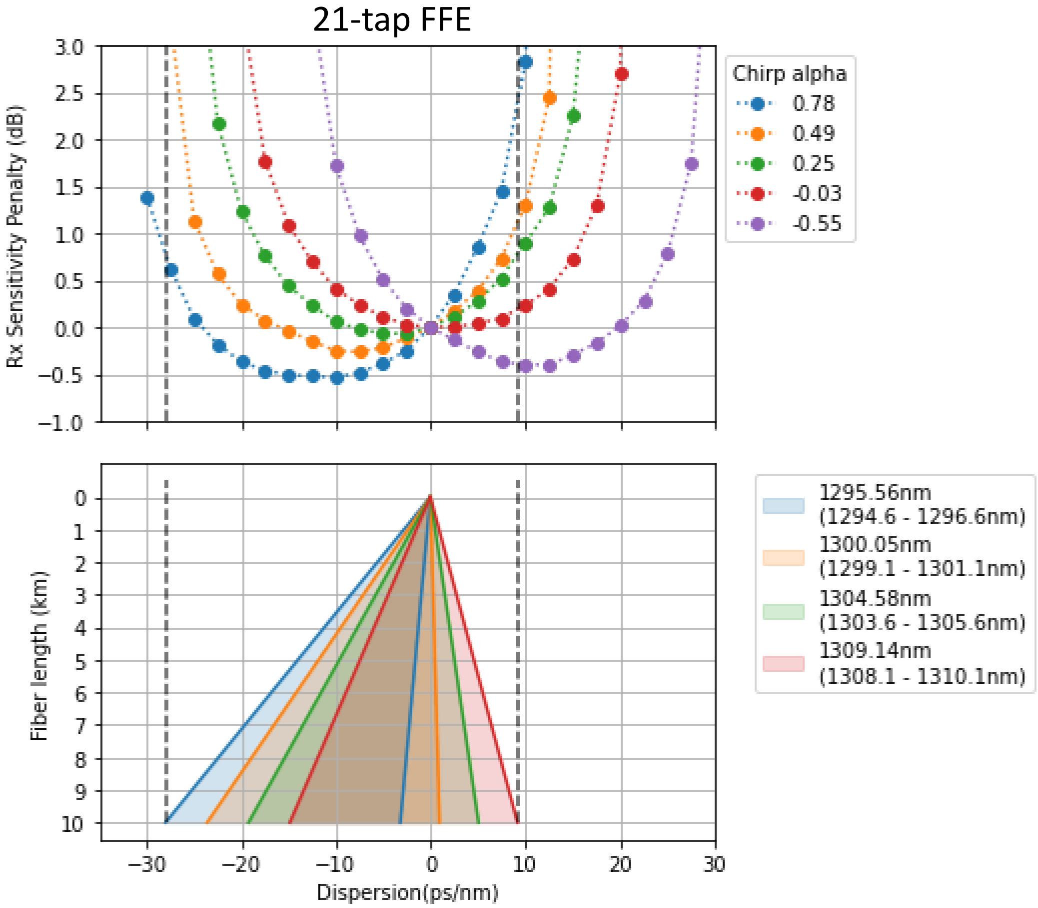
Wavelength Plan

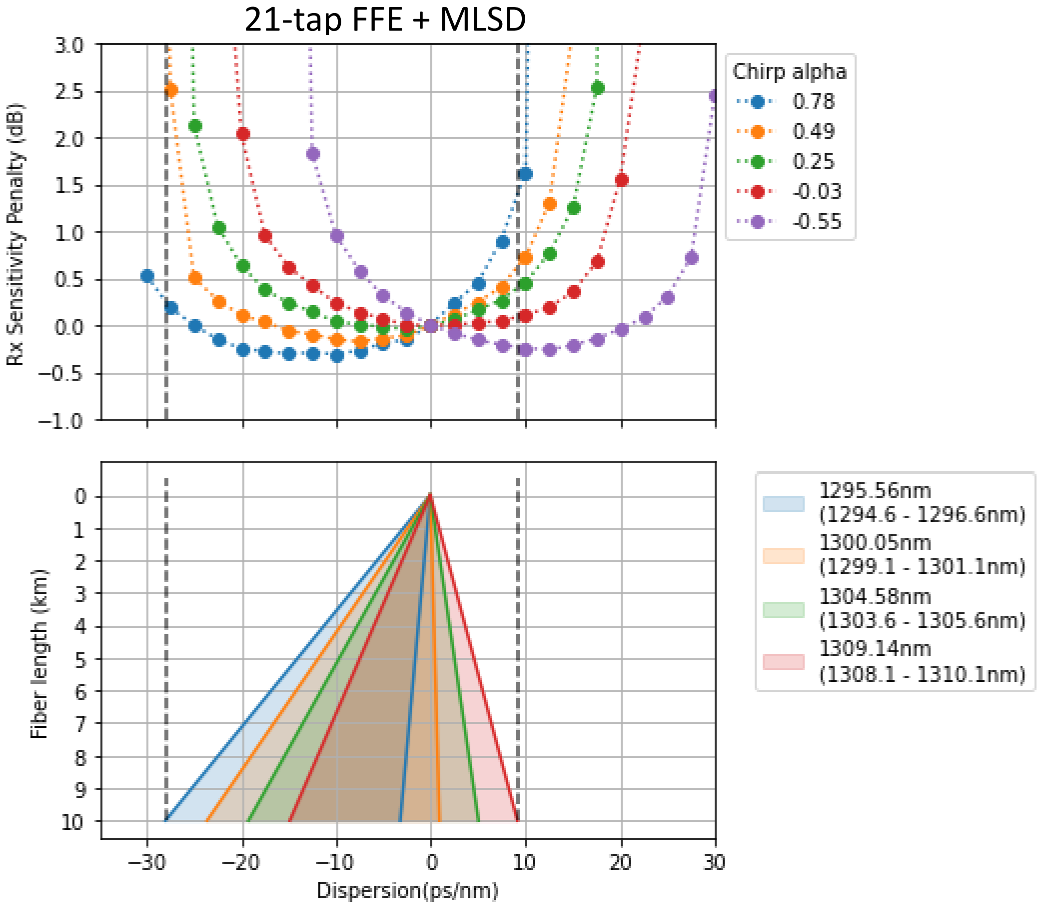
- LAN-WDM wavelengths:
  - 1295.56nm, 1300.05nm, 1304.58nm and 1309.14nm
- 800GHz spacing
- Grid previously used for:
  - 100G-LR4 & ER4
  - 200G-LR4
  - 400G-LR8



Chromatic Dispersion Simulations

- Chromatic dispersion is manageable using LAN-WDM over 10km
- Chirp management minimizes CD penalty
- MLSD provides extra tolerance to dispersion
- Good agreement with experimental data in [kuschnerov_3df_02_221012]()

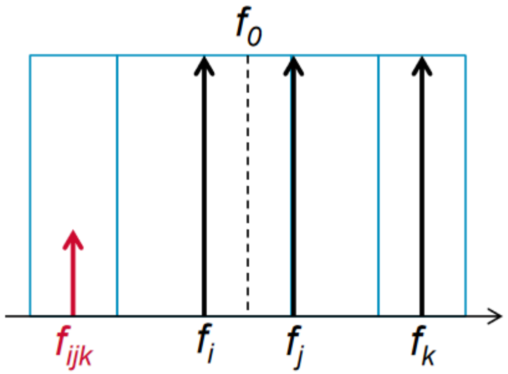




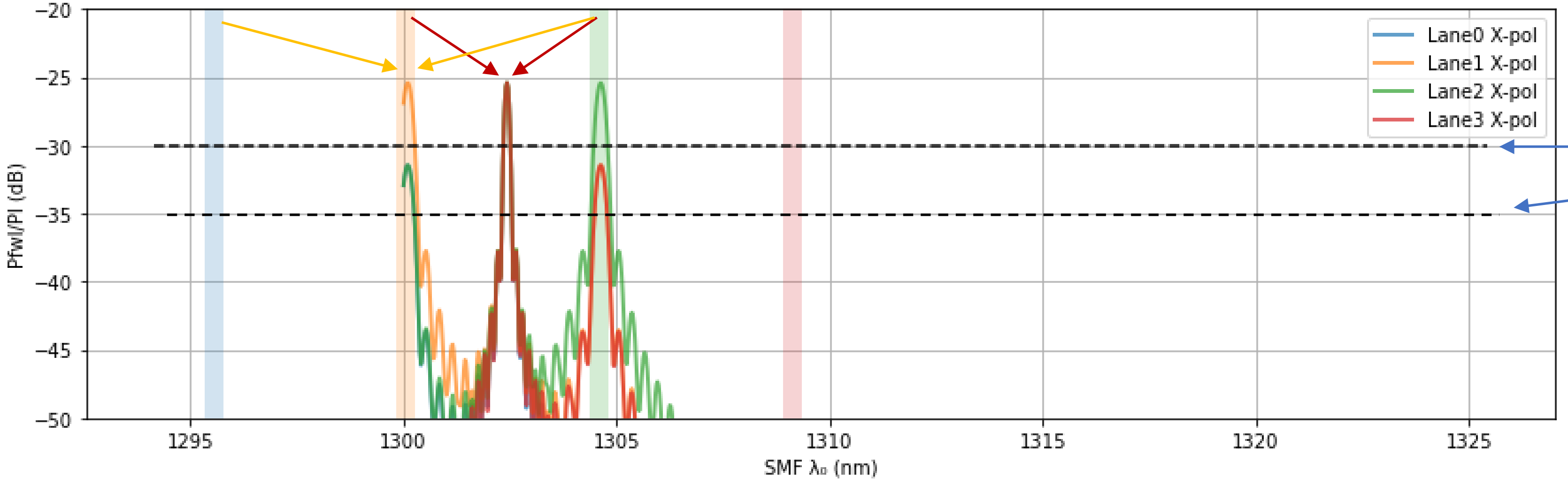
Four-Wave Mixing

- FWM conversion efficiency is maximum when the zero-dispersion frequency, f0, is centered between two of the input frequencies

johnson_3ca_1_0716



worst case FWM vs SMF zero-dispersion wavelength



Limit for penalty < 0.9dB

Limit for penalty < 0.4dB

kuschnerov_3df_02_221012

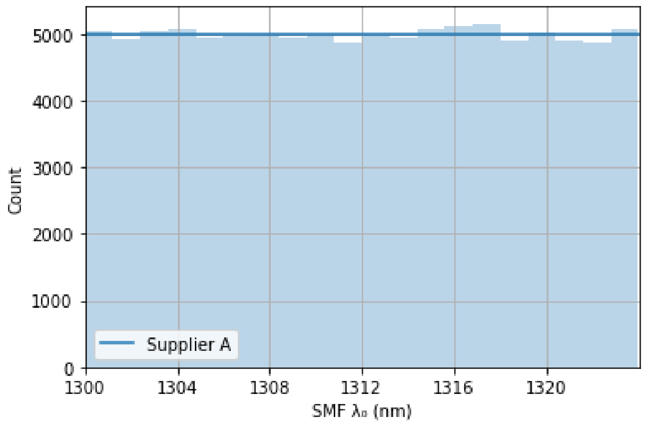
LAN-WDM has potential FWM problem if the fiber has zero-dispersion lambdas: 1300.1nm , 1302.4nm and 1304.6nm

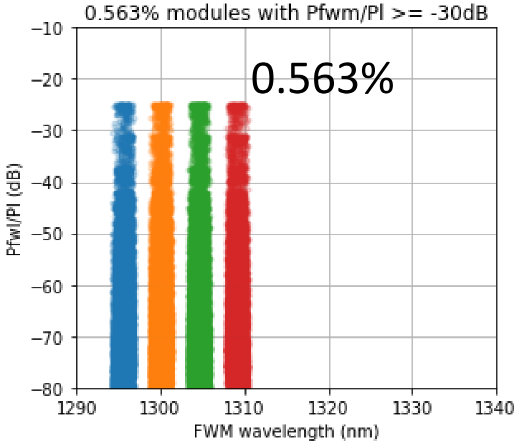
MonteCarlo Analysis on FWM Probability

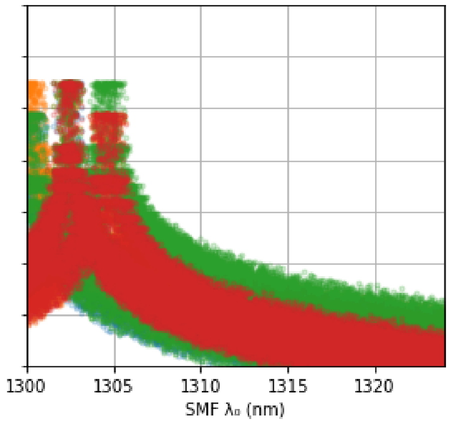
MC parameters:
- 100,000 iterations
- Tx AOP = 4.2dBm

Showing only in-band FWM components

<u>Assuming Fiber ZDW distribution is uniform</u>







In this scenario, ‘XYYX’ polarization can effectively suppress FWM effect, as shown in simulations in *liu_3df_01a_221012*, and experimentally in *lewis_3df_01_221012*

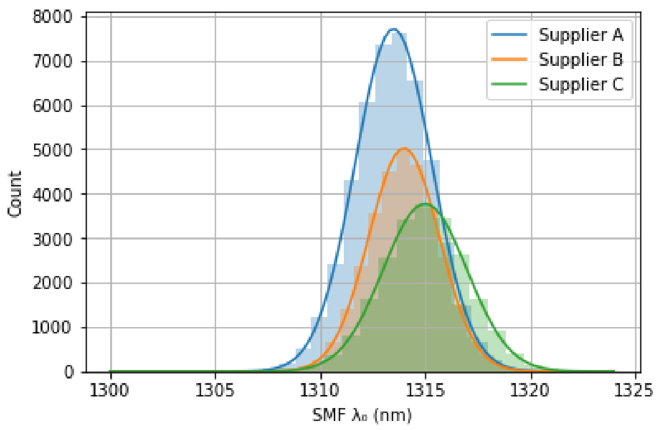
liu_3df_01a_221012:
“Even under the worst-case alignment of ZDW and laser frequencies, the FWM-induced “outage” is <10^{-3} for a 1dB penalty and a signal launch power of 5dBm per channel.”

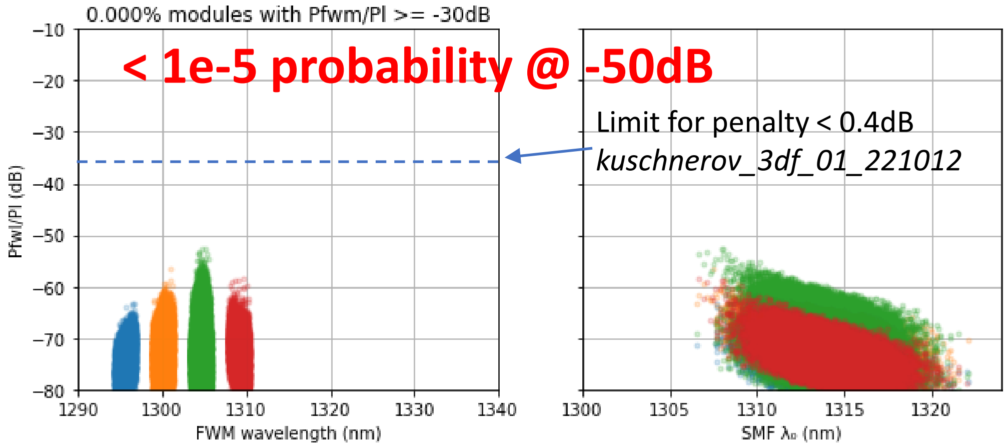
MonteCarlo Analysis on FWM Probability

MC parameters:
- 100,000 iterations
- Tx AOP = 4.2dBm

Showing only in-band FWM components

Assuming Fiber ZDW distribution based on manufacturer data (40% of market share)

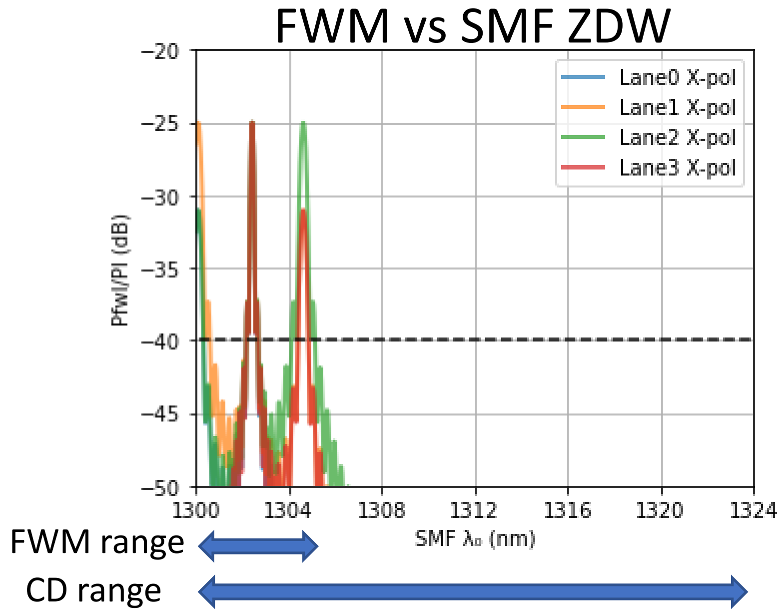


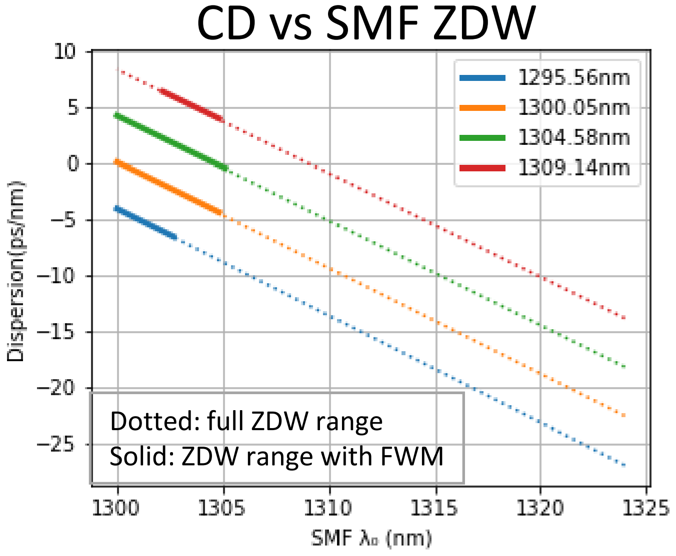


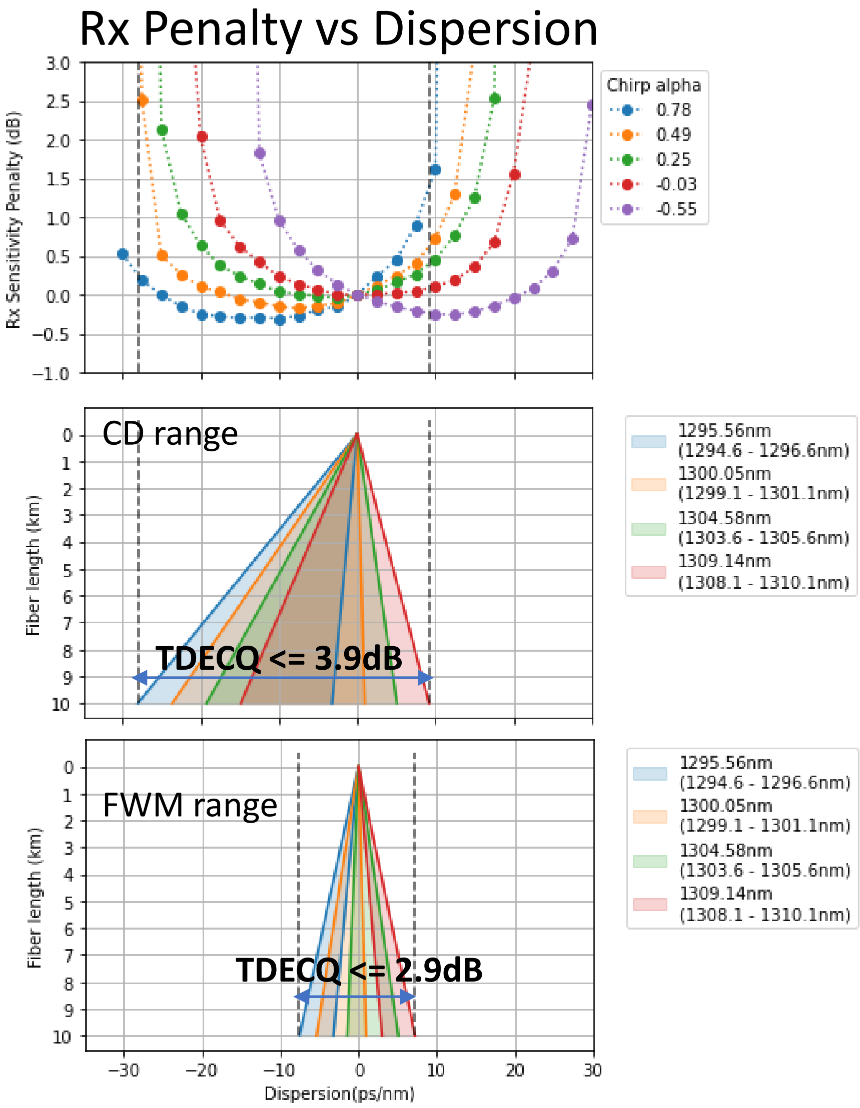
In a realistic deployment scenario, the ZDW range is much narrower and FWM effect is negligible.
Uniform distribution of ZDW is unrealistic and it overestimates FWM probability

Combining CD + FWM

- With the proposed wavelength plan, FWM tents to increase when the fiber ZDW is closer to 1300nm
- The dispersion impairment for low fiber ZDW is significantly reduced
- FWM and CD do not add on a worst-case basis
- Possible solution:
  - TDECQ inside “FWM Range” <=2.9dB (dependent on FWM penalty allocation)
  - TDECQ outside “FWM range” <=3.9dB
  - Keeping TDECQ + FWM always lower than max TDECQ





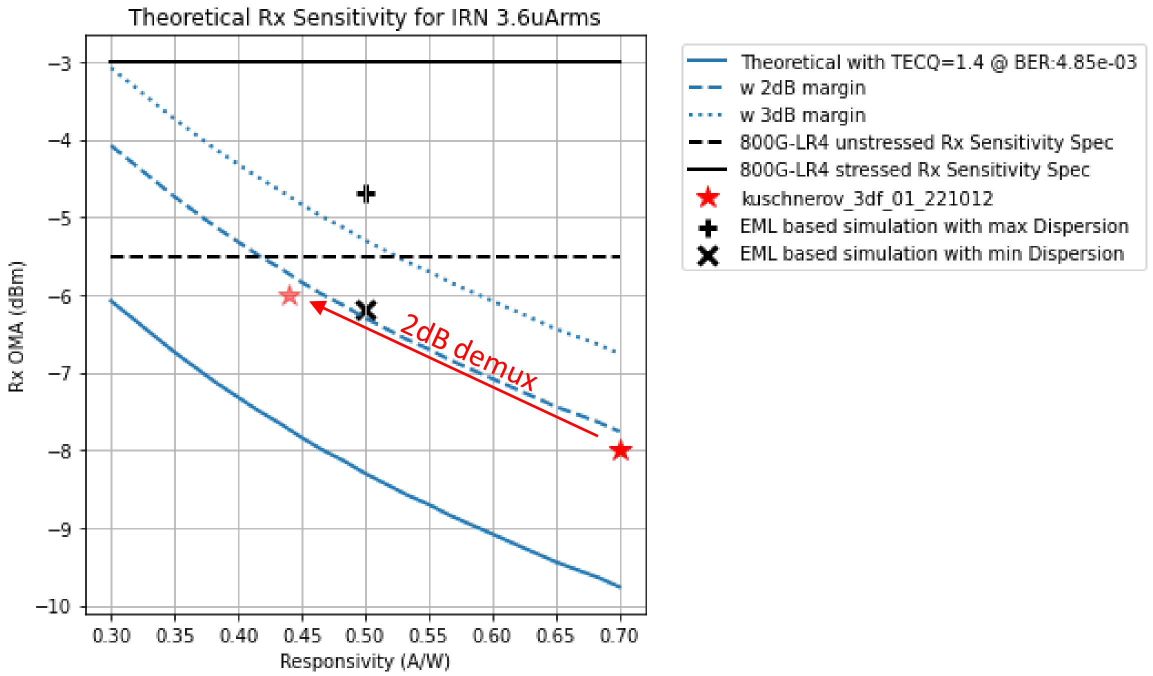


Rx Sensitivity Analysis

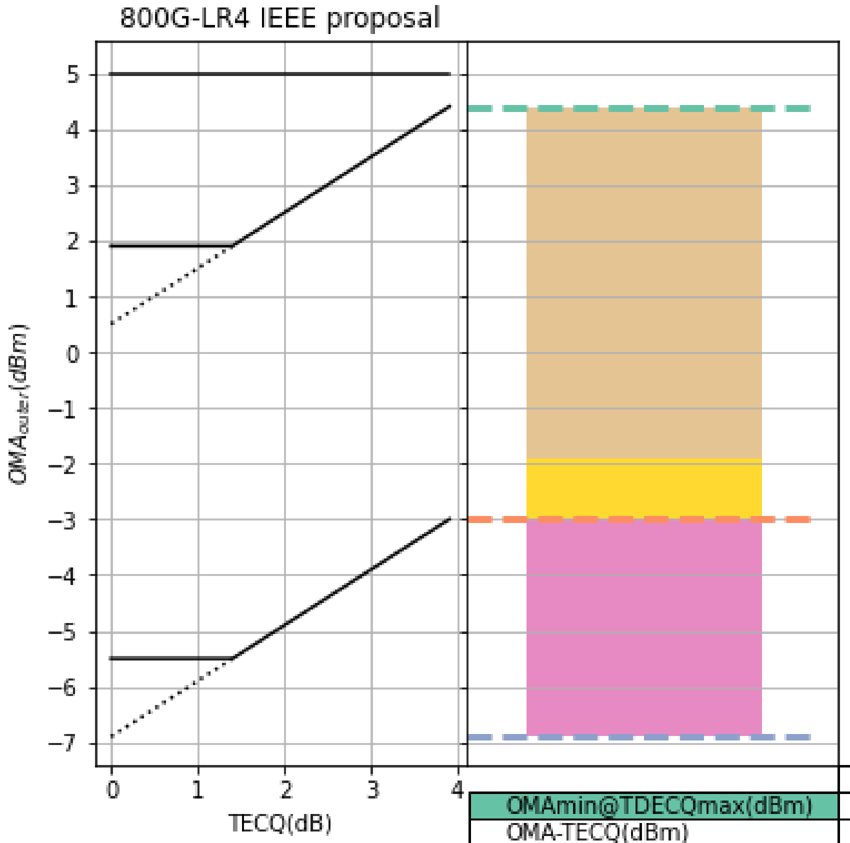
No module data available yet, however:

- Theoretical calculations and Simulations performed using responses based on fabricated devices (EML, driver and TIA) indicate that -5.5 dBm unstress Rx Sensitivity spec is achievable with manufacturing margin
  - No MLSE considered, only FFE equalization

- Experimental Rx sensitivity of -8dBm with stressed Tx has been demonstrated for single lane (*kuschnerov_3df_02_221012*)



Power Budget and Spec Proposal



	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

Additional penalties: DGD= 0.7dB and MPI= 0.4dB

(*kuschnerov_3df_01a_221012*, *kuschnerov_3df_02_221012*)

Transmitter	
OMA outer, each lane, min TDECQ<1.4dB 1.4dB < TDECQ <= 3.9	 1.9 dBm 0.5 + TDECQ dBm
TDECQ max	3.9 dB
TDECQ limited dispersion	2.9 dB
TECQ max	2.9 dB

Receiver	
RS, each lane max TECQ<1.4dB 1.4dB < TECQ <= 3.9	 -5.5 dBm -6.9 + TECQ dBm
SRS max	-3.0 dBm

Budget	
Power Budget	11.3 dB
Channel Insertion Loss	6.3 dB
Allocation for penalties	5.0 dB

Conclusion

- While we wait for experimental data in the next months, simulation analysis shows 800G-LR4 is technically feasible in LAN-WDM grid
- FWM probability is greatly overestimated when using uniform distribution of fiber zero-dispersion wavelength
- It is possible to allocate penalty to cover the unlikely event of FWM
- Maximum Chromatic dispersion and FWM are mutually exclusive, and both penalties should be combined

Thank you