Refined 800G-LR4 IMDD optical specifications

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Outline

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- 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, $f_0$, is centered between two of the input frequencies.

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

Assuming Fiber ZDW distribution is uniform

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

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

Showing only in-band FWM components

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.

< 1e-5 probability @ -50dB

Limit for penalty < 0.4dB

kuschnerov_3df_01_221012
Combining CD + FWM

- With the proposed wavelength plan, FWM tends 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](#))
Transmitter
OMA outer, each lane, min
TDECQ < 1.4 dB
1.4 dB < 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 < 1.4 dB
1.4 dB < 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

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

(kuschnerov_3df_01a_221012, kuschnerov_3df_02_221012)
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