Update on component and channel characterization for optical 200G PAM4

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Outline

- Optical 224Gb/s PAM4 Rx sensitivity update
- Simulated vs. measured CD penalty (FR4, LR4 use cases)
- Experimental FWM penalty analysis
- Numerical MPI penalty derivation for 10km

Motivation

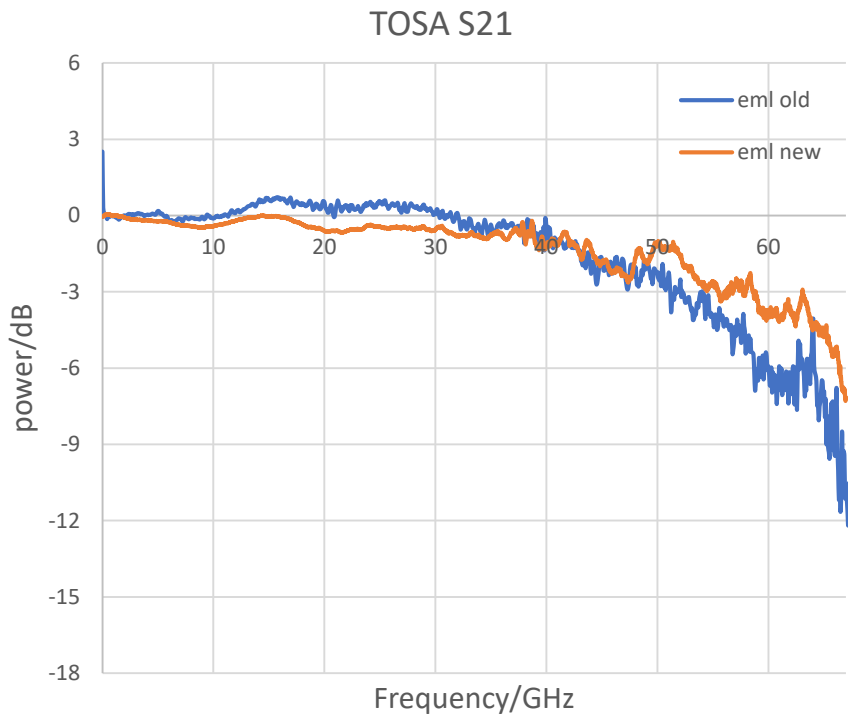
- A link budget analysis and proposal have been made for the 800G LR4 IM-DD solution in rodes_3df_01c_2207
- So far only numerical data have been shown for various fiber impairments such as CD, FWM and DGD for the 10km IM-DD solution
- This work focuses on the experimental update on the receiver sensitivity, and an experimental assessment of CD and FWM channel impairments
- We will assume a stronger FEC RS(544,514)+Hamming(128,120), as in patra_3df_01a_2207, with BER threshold at 4.85E-3

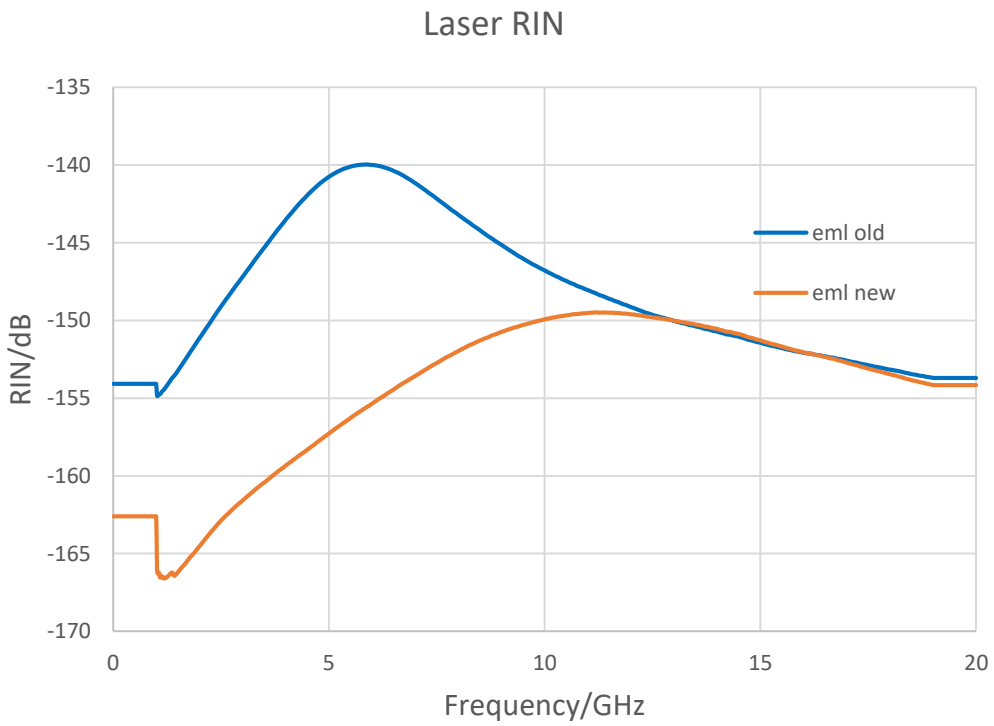
Previous Results

- Our previous presentation, kuschnerov_3df_01_220222, has shown an analysis of 200 Gb/s optical feasibility based on PD+TIA packaged devices
- The demonstration of 224Gb/s PAM4 transmission was based on packaged TOSA (driver+EML) & and ROSA (PD+TIA) subcomponents
- The EML performance was not fully optimized due to the device interconnections
- A resulting receiver sensitivity of ~-7 dBm (-7.66dBm Rx OMA) was demonstrated.
- The CD penalty analysis was based on a numerical analysis

Update on optical 224Gb/s PAM4 receiver sensitivity

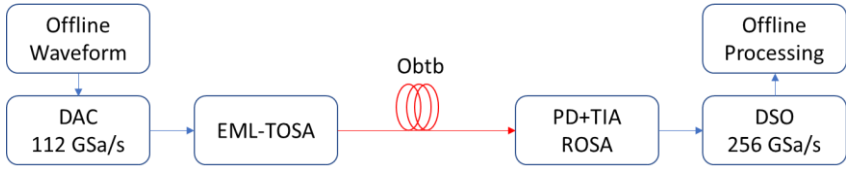
- Updated measurements: Optimized TOSA bandwidth and reduced laser RIN



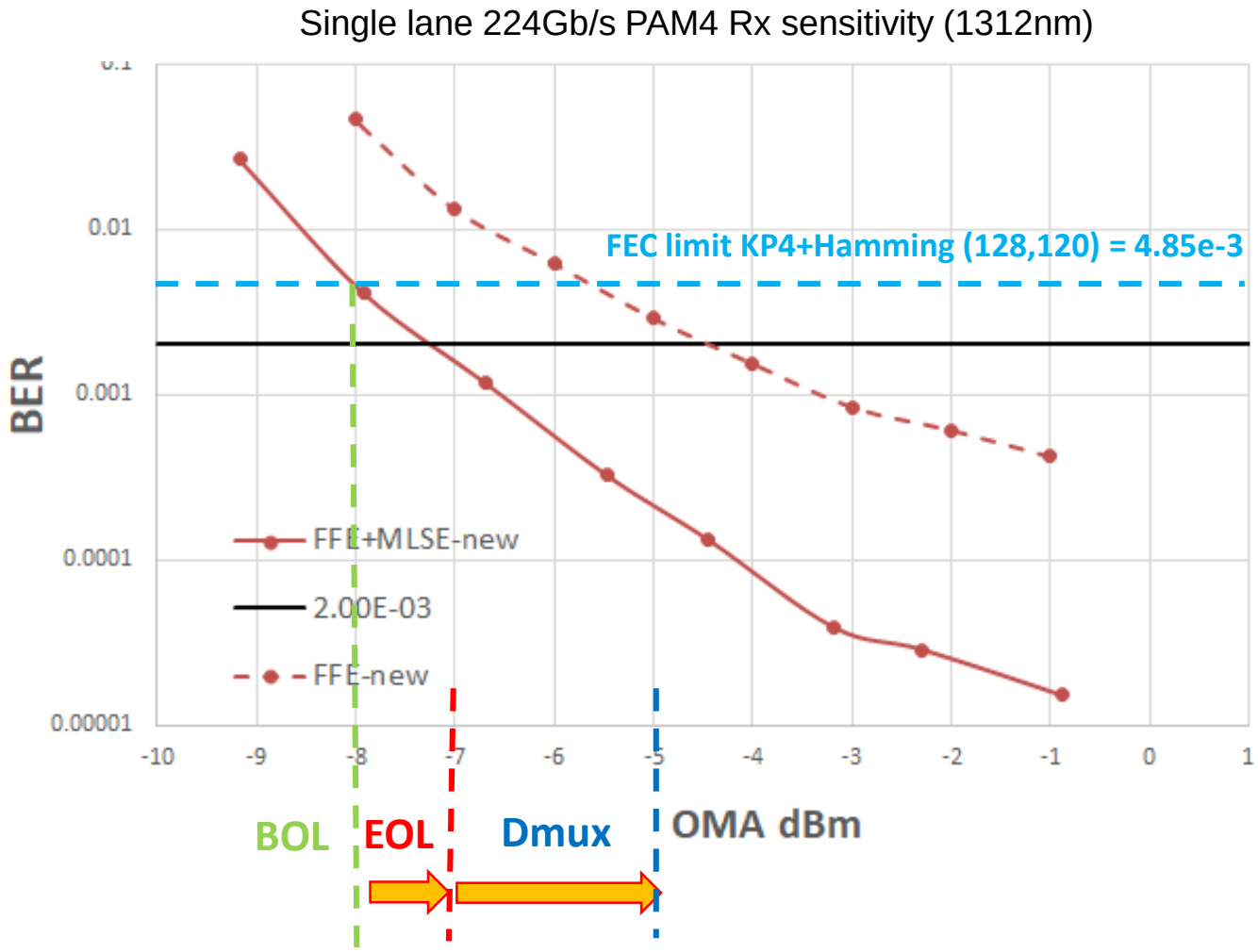


Update on optical 224Gb/s PAM4 receiver sensitivity

- Experimental setup as in kuschnerov_3df_01_220222*



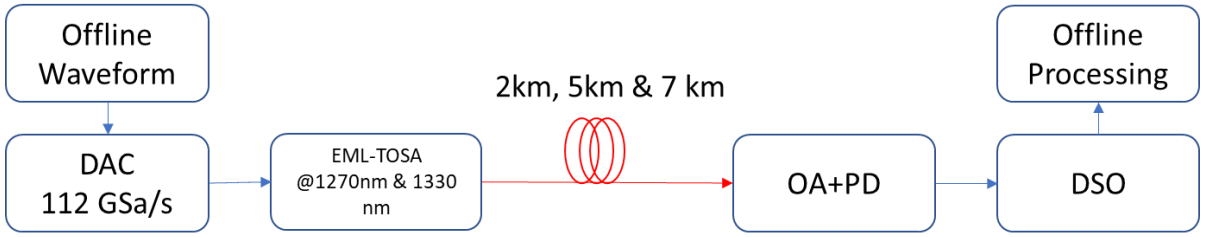
- Optimization of the TOSA bandwidth
- Rx OMA of -8 dBm @ 4.85e-3 FEC was achieved with single lane PD+TIA.
- Considering 2 dB demux loss and 1dB EOL aging margin, a sensitivity of -5 dBm could be feasible
- Note: This is a “stressed” receiver with a transmitter penalty which is likely higher than 1.4dB for now

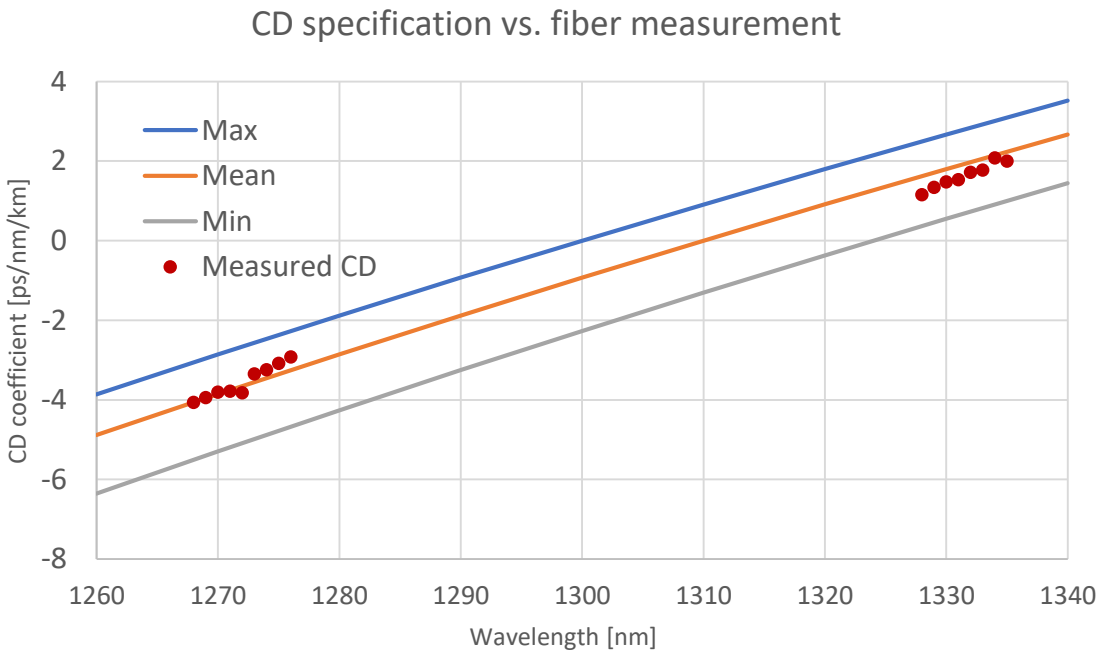


*FFE length = 41 taps (longer due to longer RF cables). MLSE: 2-state soft output for 1+alpha*D channel

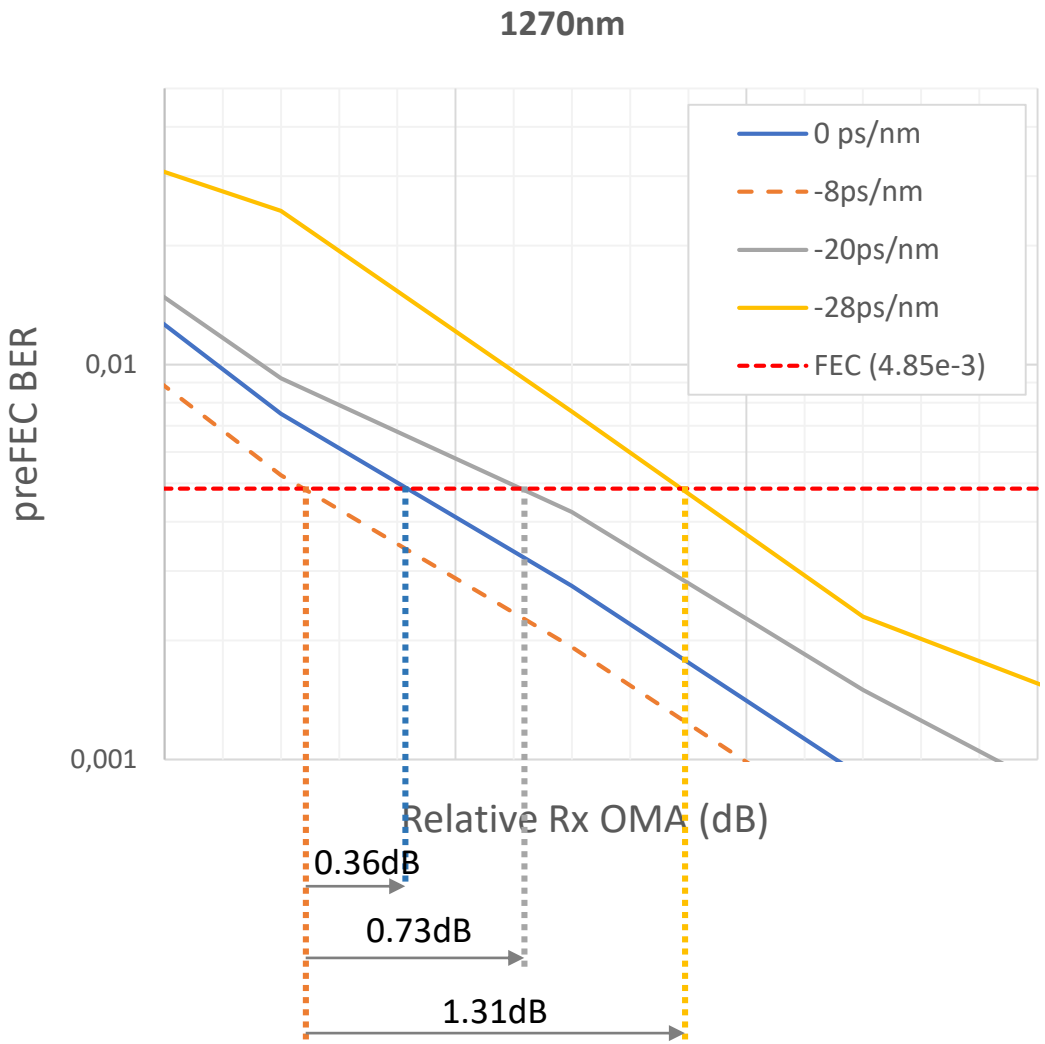
CD penalty analysis: Fiber measurement

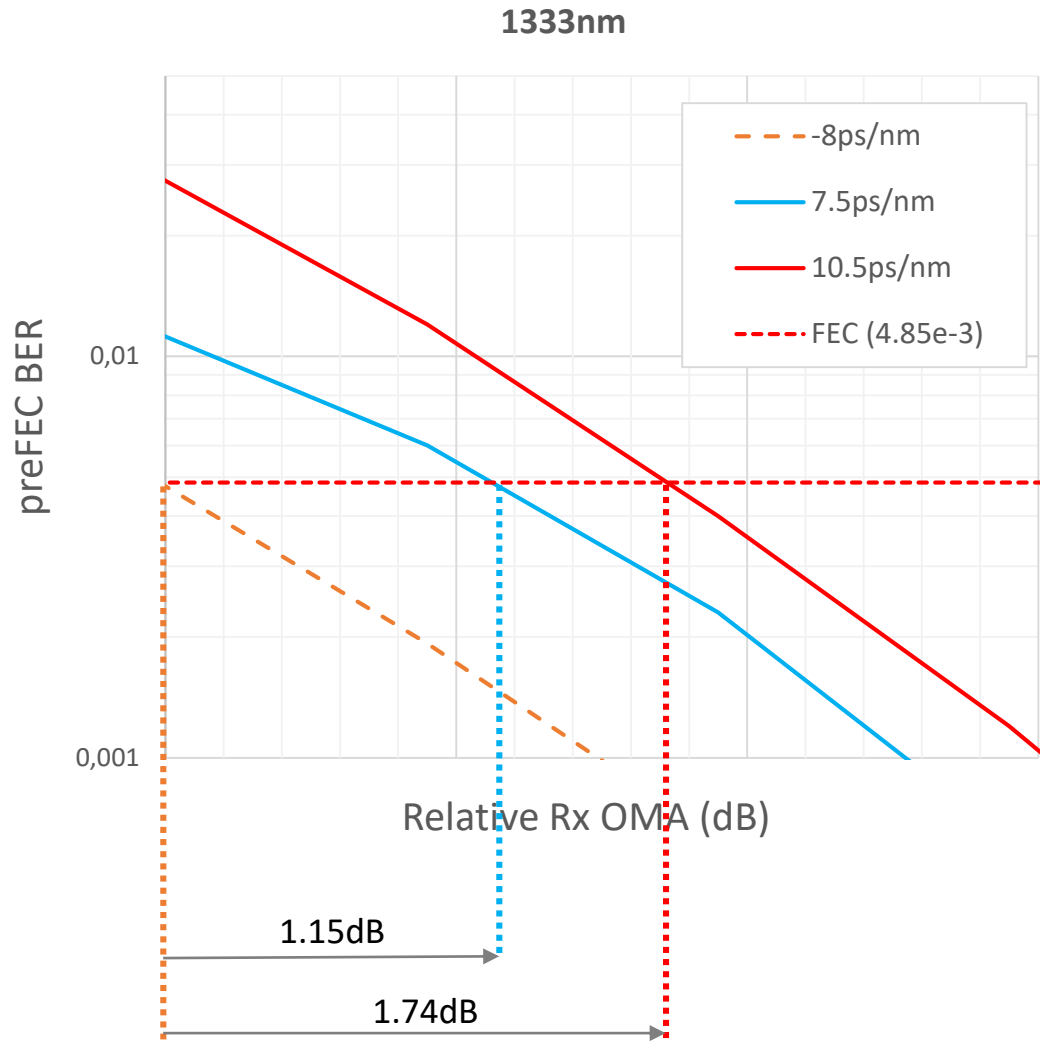
- This experiment utilizes the 1270nm & 1333 nm EMLs as transmitter with various length of fibers to emulate the dispersion values in LWDM ranges
- The fiber dispersion was calibrated using 1270nm and 1330 nm wavelength ranges respectively
- In the figure, the measured results are shown in the figure overlaid with ITU-T G.652 specifications





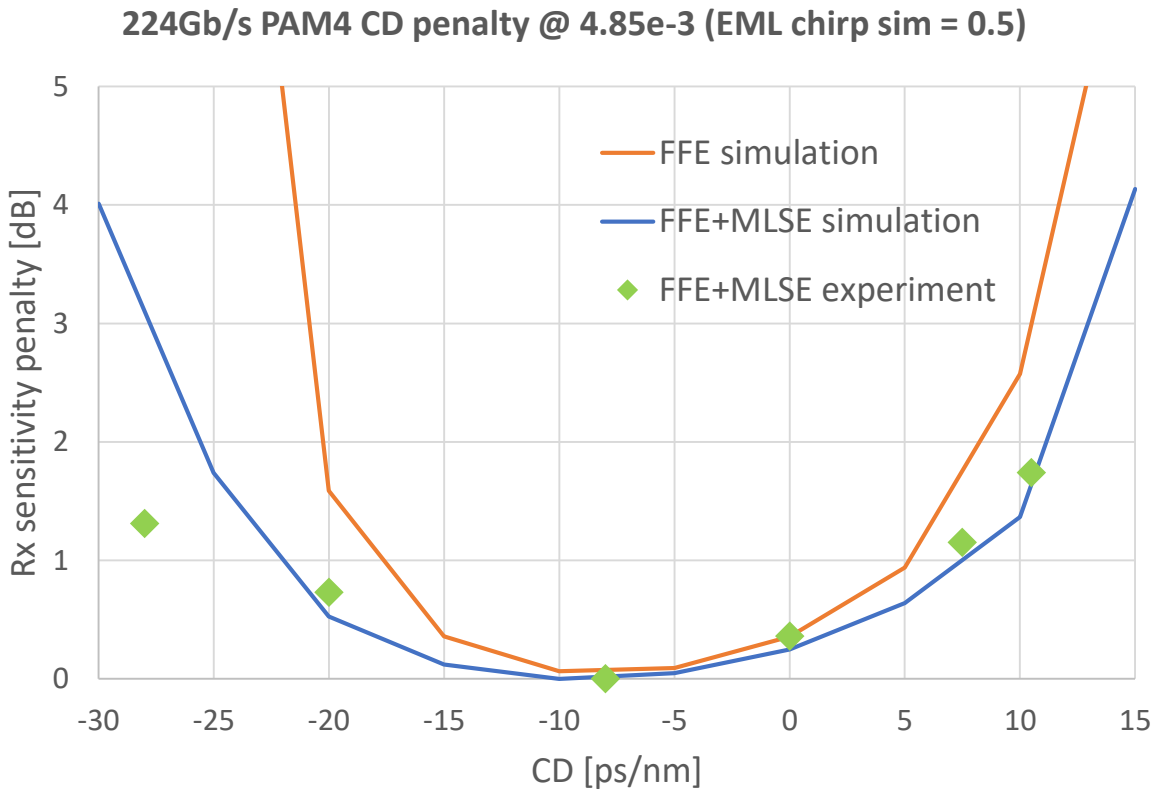
CD penalty analysis: 224Gb/s PAM4 transmission

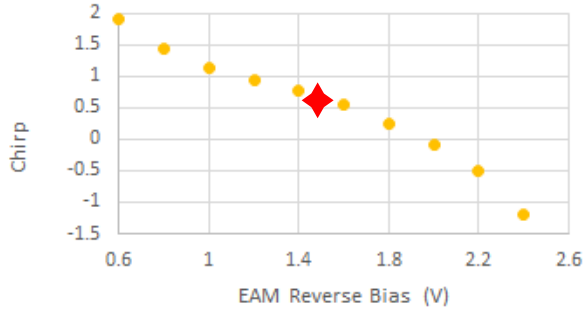




224Gb/s PAM4 CD penalty: Simulation vs. experiment

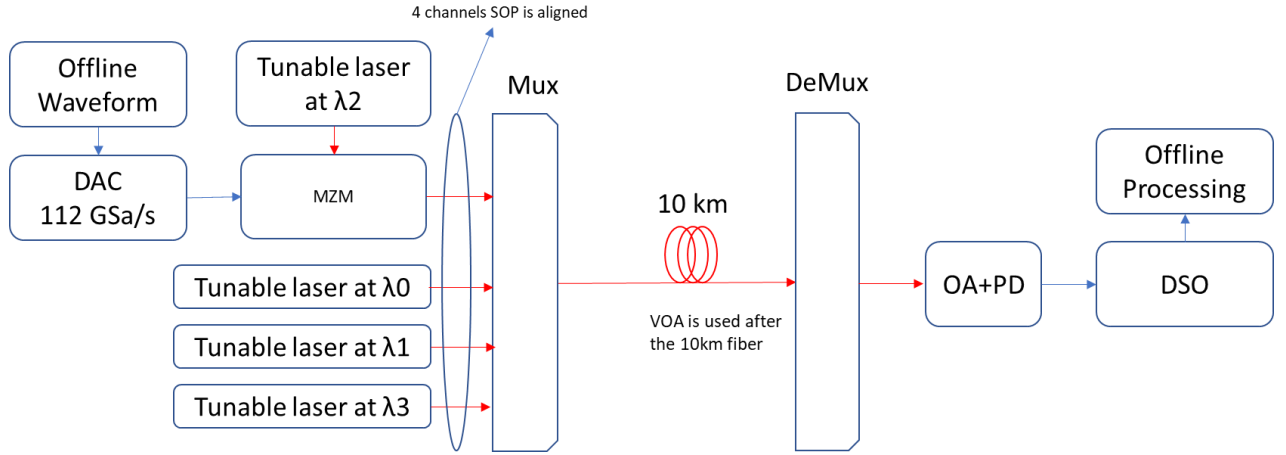
- kuschnerov_b400g_01_210503 presented the CD penalty for 224Gb/s PAM4 using FFE and FFE+MLSE receivers
- Figure shows overlay of measured and simulated results
- Mostly good agreement between simulations and measurements
- Deviation from simulation due to EML being driven at chirp = 0.6 in the measurement:



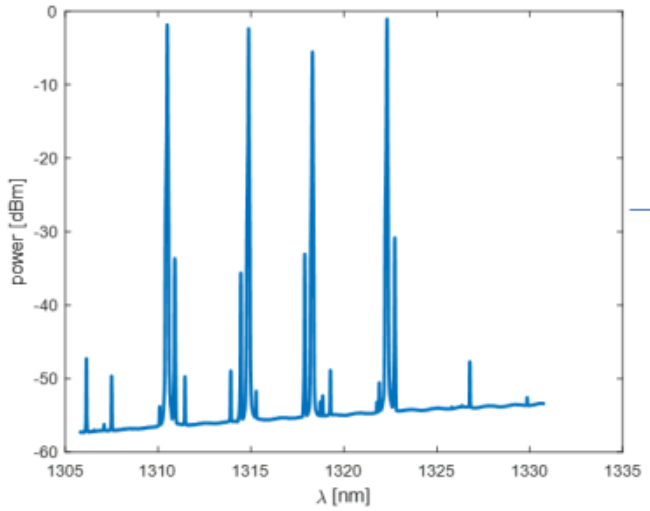


Experimental FWM penalty analysis

- Four tunable lasers used for wavelength alignment
- As stated in johnson_3df_optx_01_220414, FWM is unlikely to be observed in small scale lab tests.
- Large optical power (> 8 dBm in to the fiber) was applied to boost FWM, such that P_{FWM}/P_{signal} ~ -30 dB.
- As discussed in liu_3df_01b_2207, the Tx polarization between channels could be tailored to reduce penalty (XYYX polarizations)



Example of spectrum before wavelength alignment



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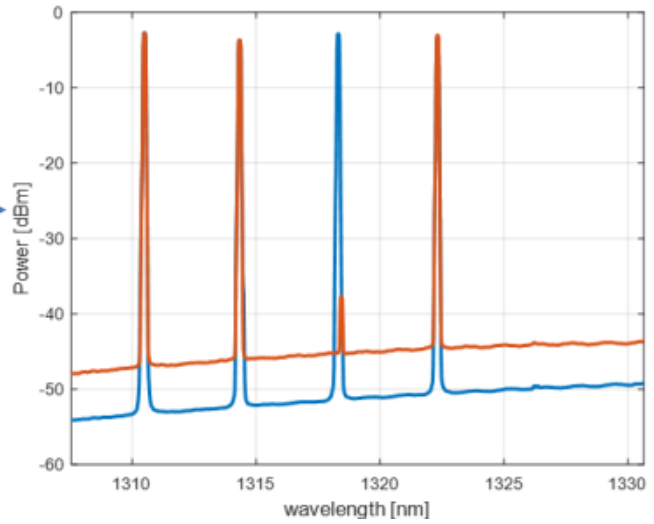
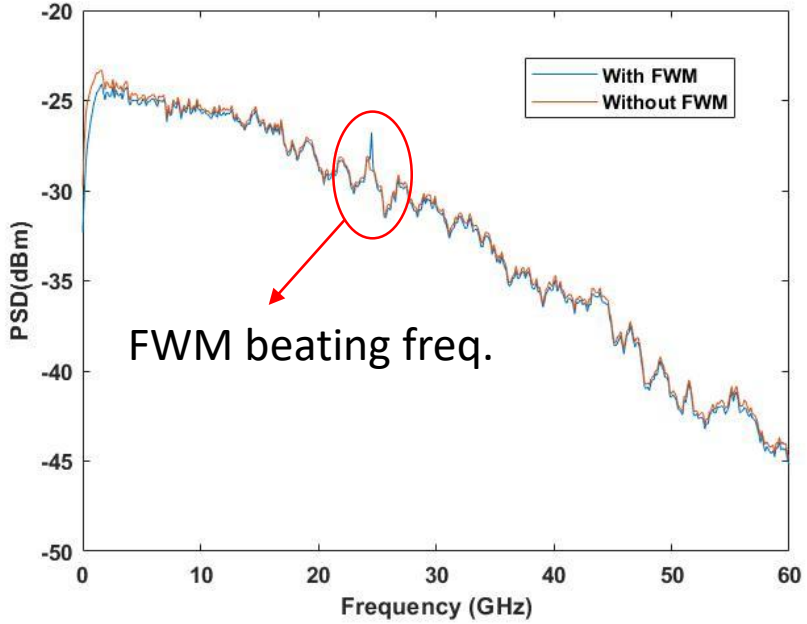
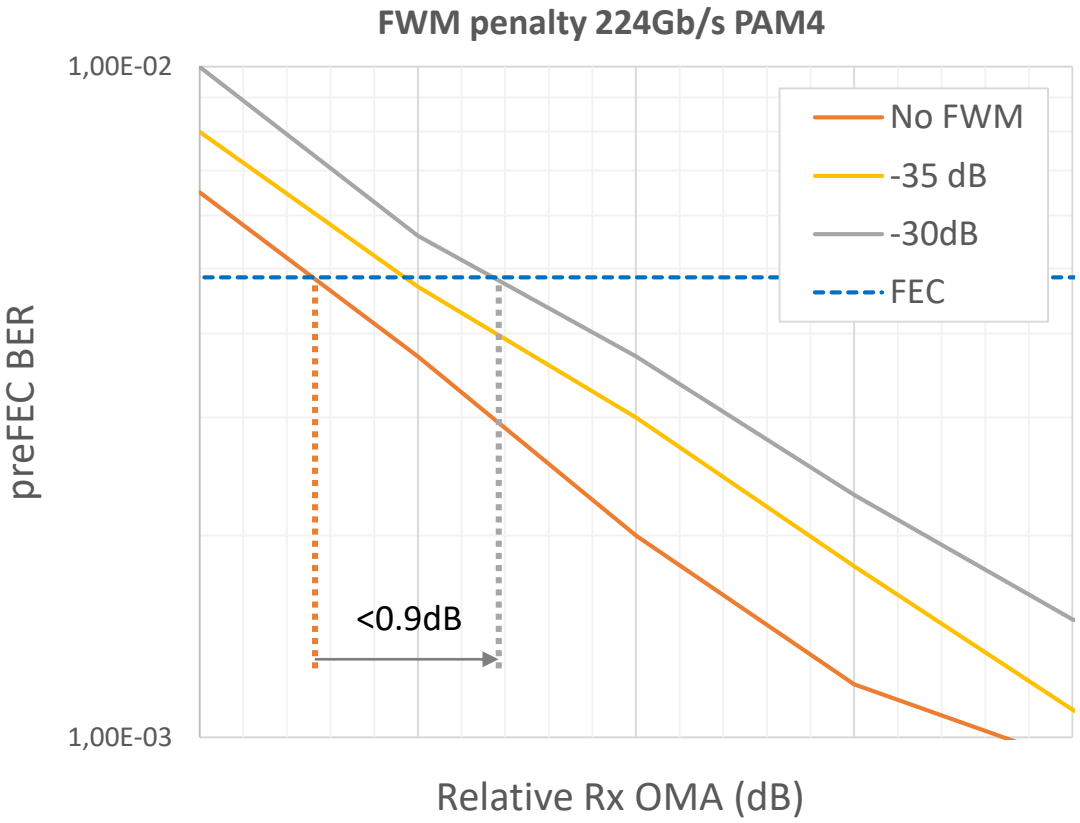


FWM transmission impact on 224Gb/s PAM4

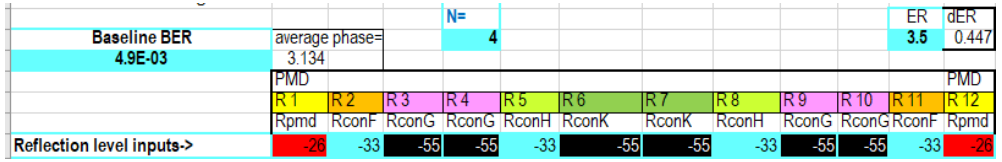
- Spikes in the power spectral density (PSD) within Nyquist frequency are observed due to FWM beating.

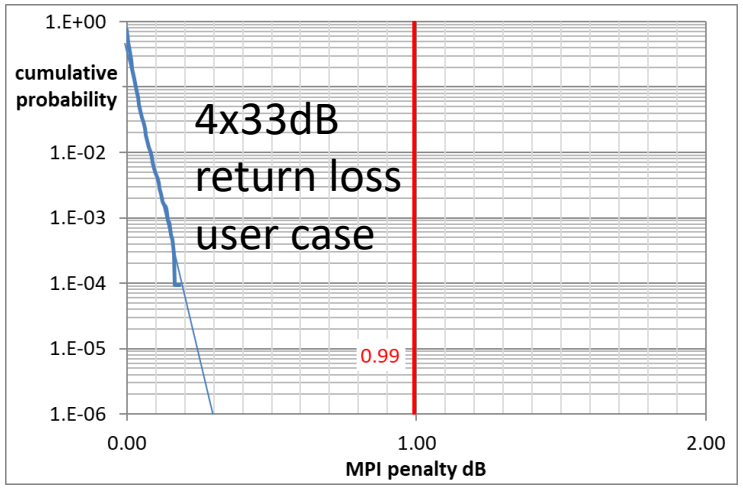




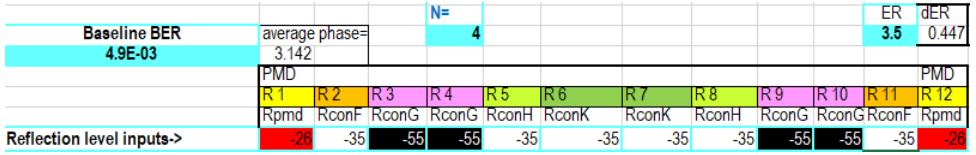
- <0.9dB penalty for P_{FWM}/P_{signal} = -30dB

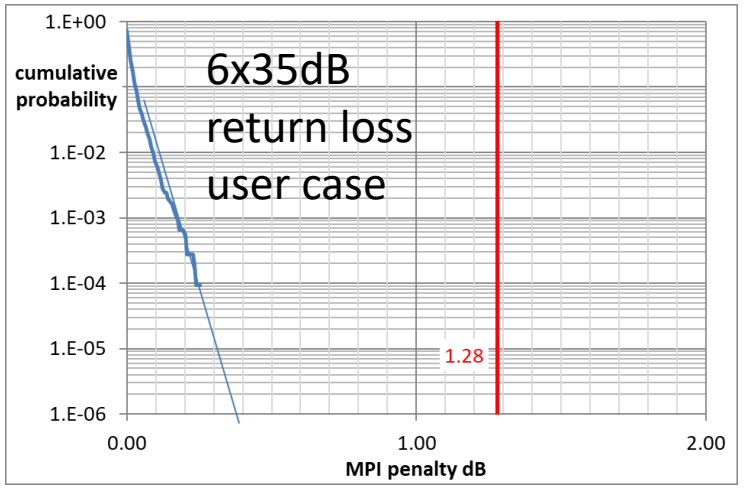
MPI penalty for 224G PAM4 LR 10km





- The MPI Penalty is calculated based on spreadsheet model from king_02a_0116_smf.7z with 1 ppm outage possibility.
- MPI depends on FEC, ER, connectors return loss
- The calculated value for 800G LR4 MPI penalty is 0.4 dB @ ER=3.5 dB, and FEC=4.85e-3





scenario	Baud Rate	Tx/Rx return loss (max)	Number of Connectors in Model	Connectors Return loss (max)	MPI penalty [a]
200G-DR4	25G	-26	4	-45 dB	0.1 dB @ KP4
400G-DR4	50G	-26	4	-45 dB	0.1 dB @ KP4
200G-FR4	25G	-26	4	-35 dB	0.4 dB @ KP4
400G-FR4	50G	-26	4	-35 dB	0.4 dB @ KP4
400G-LR8	50G	-26	6	-35 dB	0.6 dB @ KP4
800G-LR4	100G	-26	6	-35 dB	0.4 dB @ 4.85E-3

Conclusions

- High bandwidth EML & PD+TIA performance was updated. An EOL sensitivity of -5dBm per lane at the (stressed) receiver interface is feasible for 4x200G based IM-DD solutions.
- The CD penalties are analyzed using EML based techniques. Penalties for both positive and negative dispersion showed a close match between simulations and measurements and could support CWDM4 grid for FR4 2km and LAN-WDM grid for LR4 10km
- The preliminary results show that FWM penalty with random SOP is <0.9dB for P_{FWM}/P_{signal} = -30dB. The penalties could be further reduced using Tx polarization interleaving
- The MPI penalty for the 10km link is estimated to be 0.4dB