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 specification vs. fiber measurement
CD penalty analysis: 224Gb/s PAM4 transmission

1270nm

1333nm
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 $P_{\text{FWM}}/P_{\text{signal}} \sim -30$ dB.
- As discussed in liu_3df_01b_2207, the Tx polarization between channels could be tailored to reduce penalty (XYYX polarizations)
FWM transmission impact on 224Gb/s PAM4

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

- $<0.9\,\text{dB}$ penalty for $P_{\text{FWM}}/P_{\text{signal}} = -30\,\text{dB}$
### 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.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Baud Rate</th>
<th>Tx/Rx Return Loss (max)</th>
<th>Number of Connectors in Model</th>
<th>Connectors Return Loss (max)</th>
<th>MPI Penalty @ KP4</th>
</tr>
</thead>
<tbody>
<tr>
<td>200G-DR4</td>
<td>25G</td>
<td>-26</td>
<td>4</td>
<td>-45 dB</td>
<td>0.1 dB</td>
</tr>
<tr>
<td>400G-DR4</td>
<td>50G</td>
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<td>4</td>
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<td>0.4 dB</td>
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<tr>
<td>400G-LR8</td>
<td>50G</td>
<td>-26</td>
<td>6</td>
<td>-35 dB</td>
<td>0.6 dB</td>
</tr>
<tr>
<td>800G-LR4</td>
<td>100G</td>
<td>-26</td>
<td>6</td>
<td>-35 dB</td>
<td>0.4 dB @ 4.85E-3</td>
</tr>
</tbody>
</table>

#### Return Loss User Case

- 4x33dB
- 6x35dB
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 $P_{\text{FWM}}/P_{\text{signal}} = -30\text{dB}$. The penalties could be further reduced using Tx polarization interleaving.

• The MPI penalty for the 10km link is estimated to be 0.4dB.