Technical feasibility of 200G/lane optical

Maxim Kuschnerov, Lin Youxi
Huawei Technologies

03.05.2021

IEEE P802.3 B400G Study Group, Interim Teleconference, 3 May 2021

Introduction

Goal: comparison of 200G/lane PAM4 vs. PAM6 optical on demonstrator hardware and in simulations

Disclaimers:

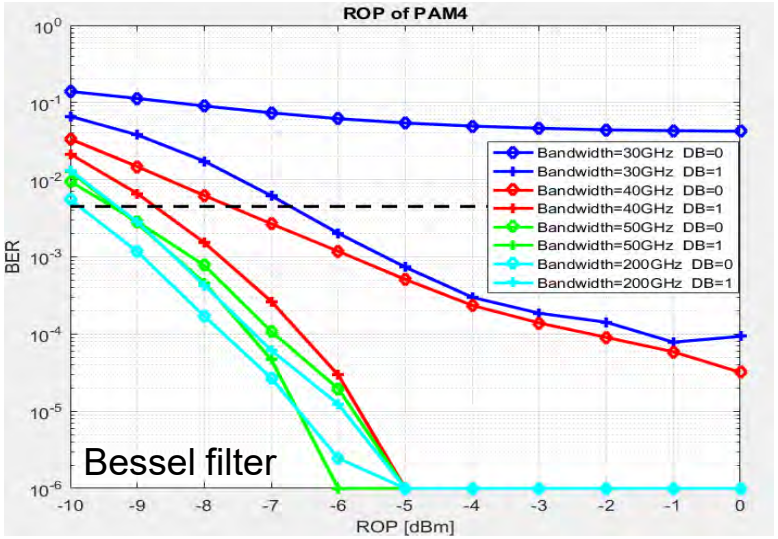
1) All results use preliminary (not final) hardware and thus are not fully representative of the actual target performance of to be defined reference receivers
2) The measurements didn't use fully integrated components. This will not be the case in products and will lead to an overall better performance
3) Measurement results for PAM4 vs. PAM6 can be assessed relatively to each other, but not necessarily in absolute terms

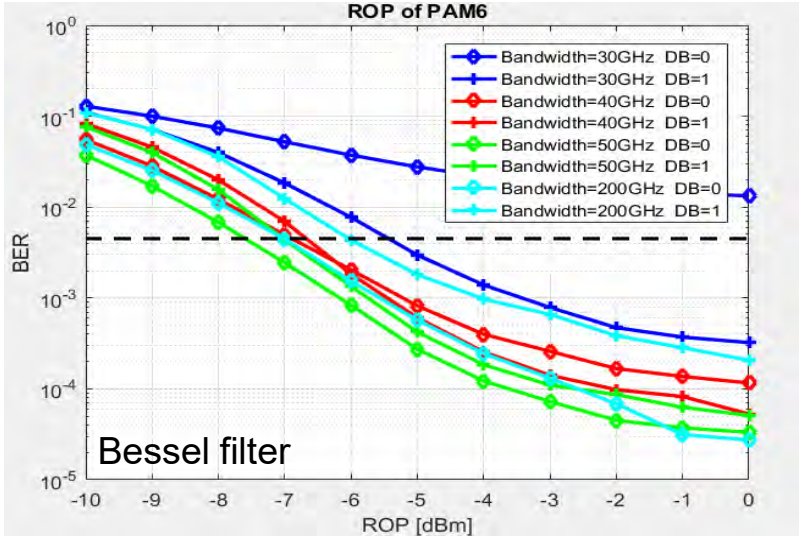
Acknowledgements:

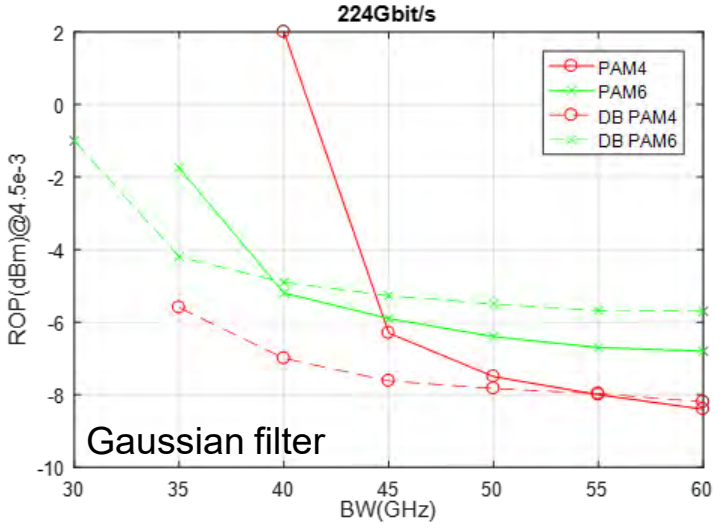
Nebojsa Stojanovic, Jinlong Wei, Talha Rahman, Peter Stassar (all Huawei)

224G optical link simulations: PAM4 vs. PAM6

- The simulated BER as a function of the received optical power (ROP) for different values of the component bandwidth.
- Components: DAC/ADC, modulator driver, EML, PIN.
- Bessel filter of 4th order and Gaussian filter of 2nd order was used.
- Bessel filter: PAM4 has ~2 dB better sensitivity with 50G components
- Gaussian filter: PAM4 has ~1.5 dB better sensitivity
- DB (duobinary): generalized partial response receiver with MLSE on/off



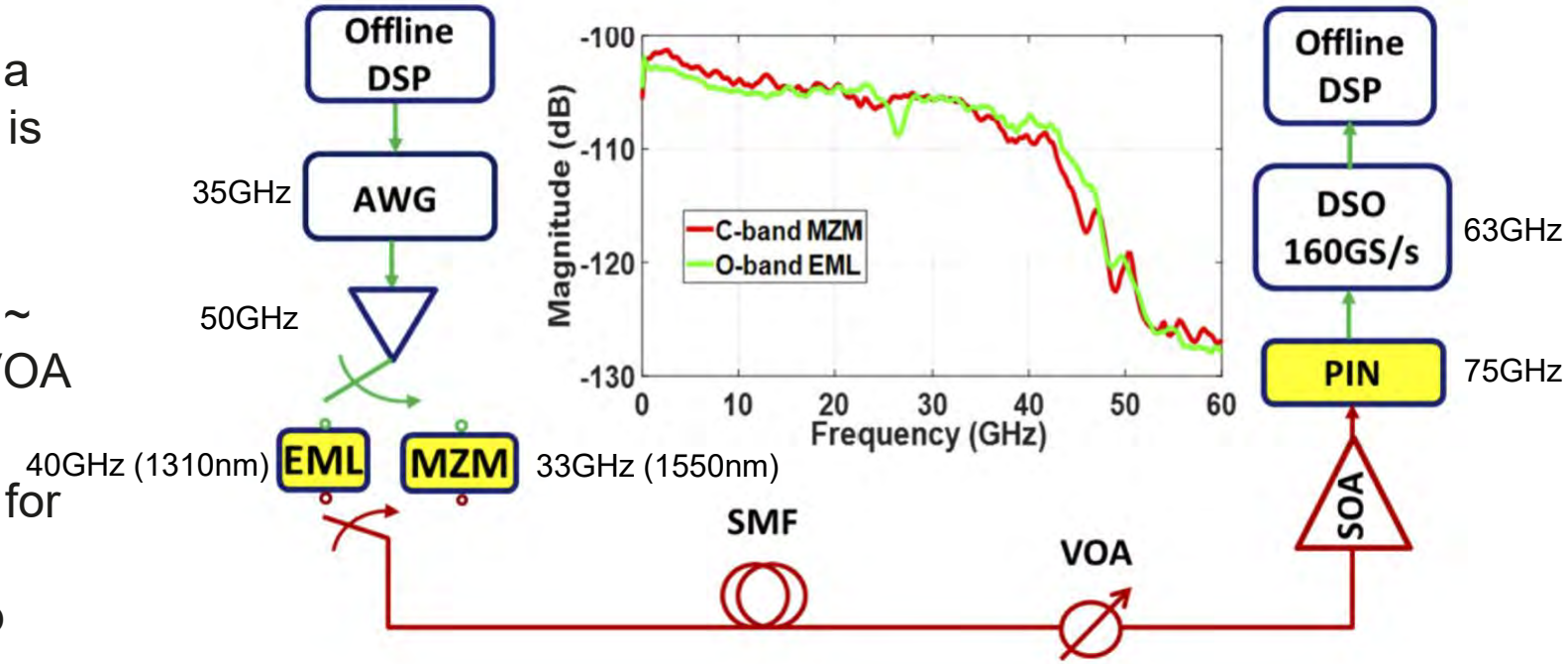




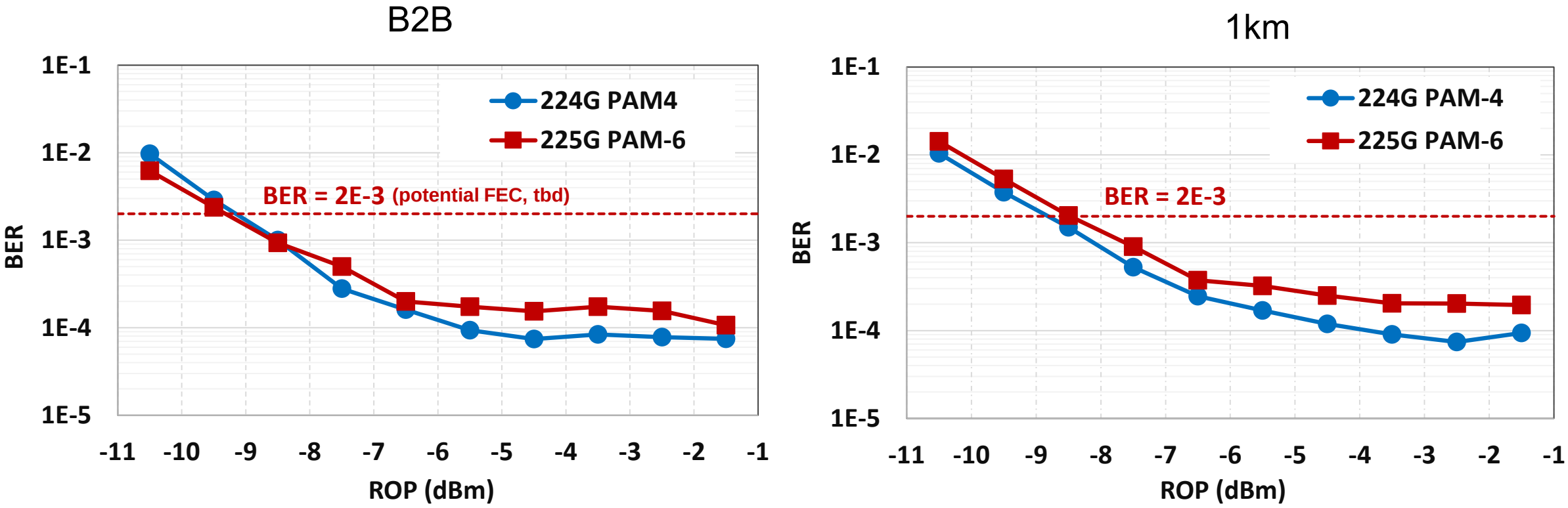
BW for each component

Measurement: MZM vs. EML

- Baseline comparison of MZM (1550nm) vs. EML (1310nm)
- EML chip on carrier is placed on a copper block where temperature is maintained by an external temperature controller
- Total optical output of the chip is ~ 9dBm with 8dB loss before the VOA
- Losses include fiber coupling losses, connectors and couplers for power monitoring in the system which are not shown in the setup
- Since, the PD does not have a TIA, SOA is used

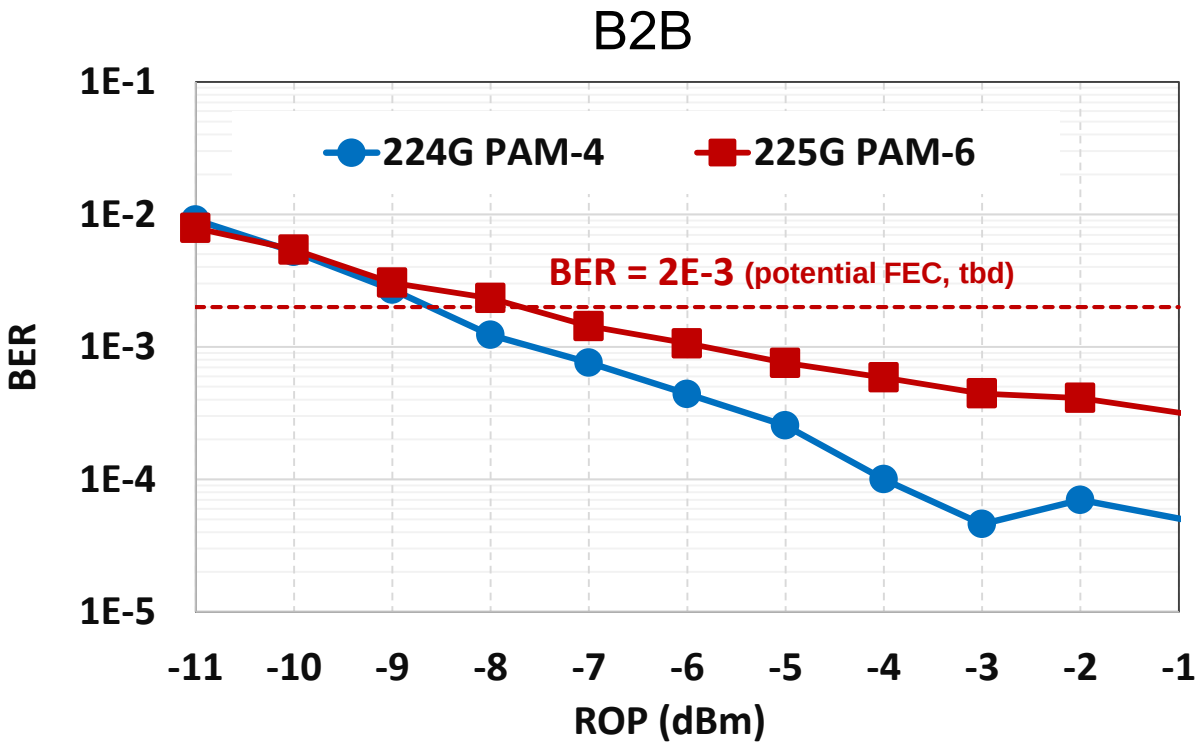


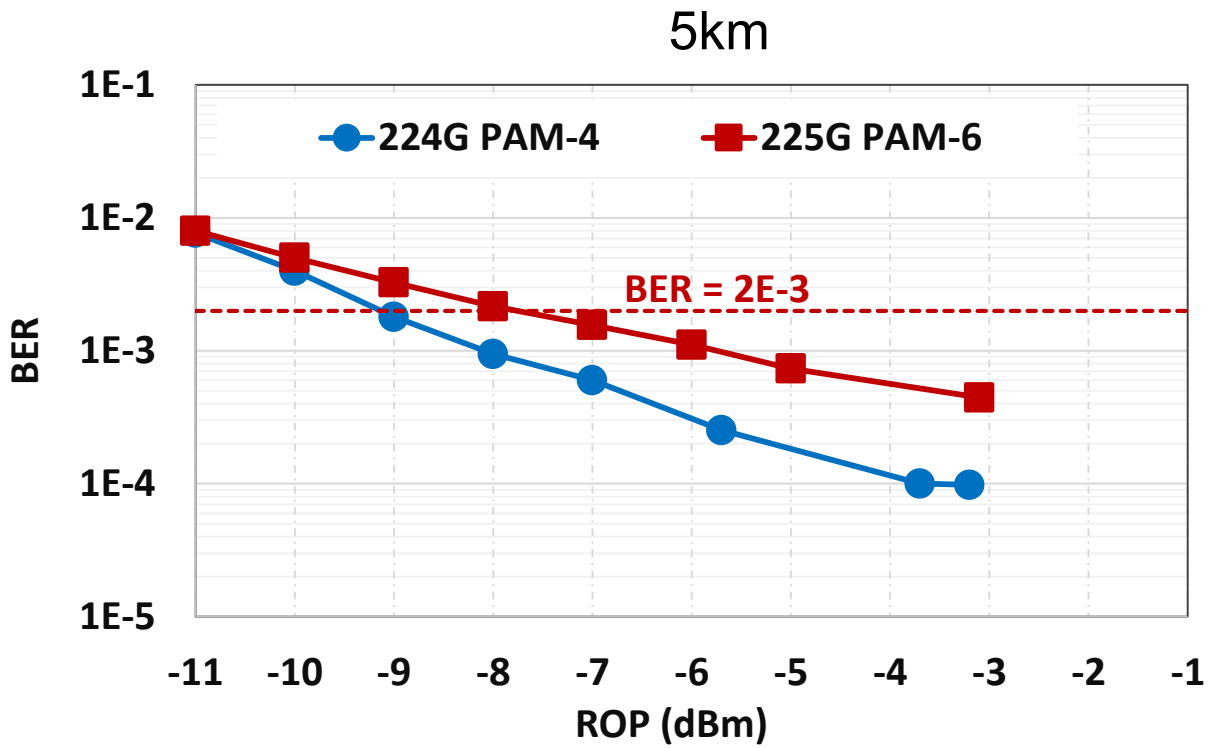
MZM evaluation 200G/lane PAM4 vs. PAM6



- Performance of PAM4 vs. PAM6 mostly similar with slight benefits for PAM4
- Transmission distance was limited due to the dispersion @ 1550nm, which would not be the case at 1310nm
- MZM transmission shows more nonlinearities compared to the EML ➔ Nonlinearities affect PAM6 much more than PAM4

EML evaluation 200G/lane PAM4 vs. PAM6



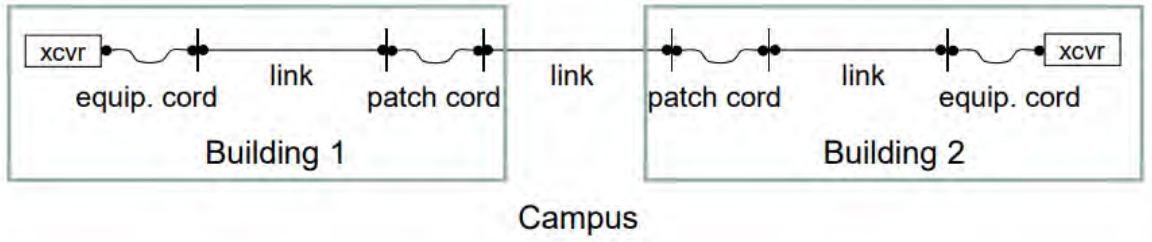


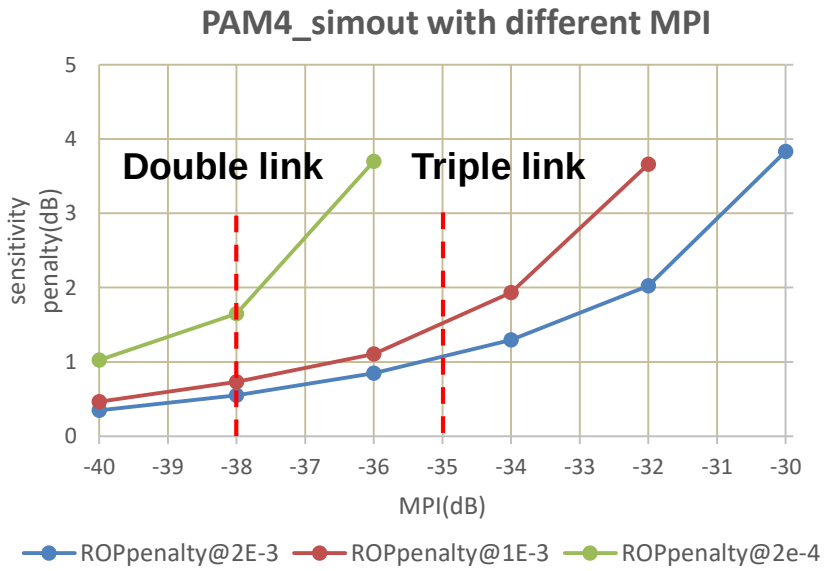
- Despite the limited Tx bandwidth vs. potential target products, PAM4 already shows a better overall performance with respect to potential link budget
- PAM6 suffers from a characteristic high error floor, which would require a better FEC in a potential product
- With further improvements on component integration and DAC/EML bandwidth, the gap between PAM4 and PAM6 is expected to widen

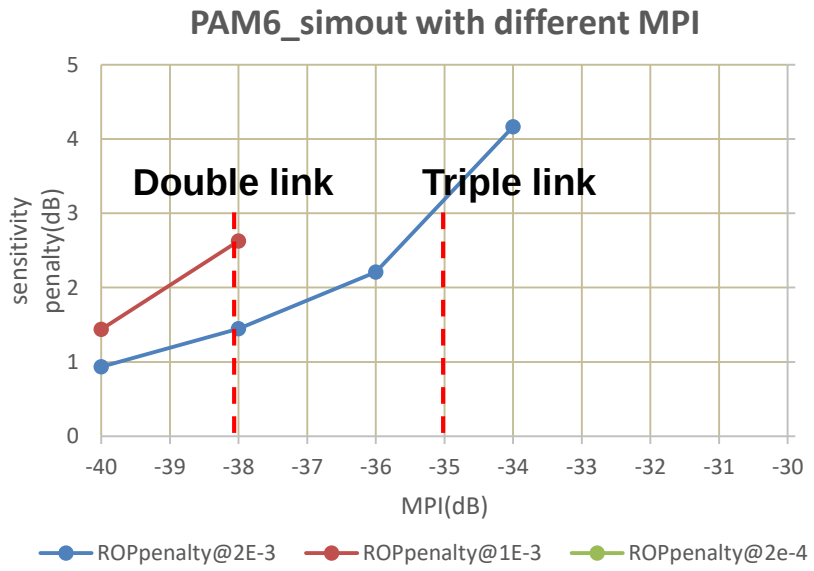
MPI penalty: PAM4 vs. PAM6

FEC limit: 2e-3	Penalty @ -38 dB (double link)	Penalty @ -35dB (triple link)
112GB PAM4	0.4 dB	1 dB
90GB PAM6	1.2 dB	3 dB

Triple link*







➔ PAM6 cannot fulfill triple link connectivity due to high MPI penalty

Note: For worst case analysis (upper bound), all reflected waves are in phase, $MPI = \left(\sum \sqrt{R_i R_j}\right)^2$ Otherwise, $MPI = \sum R_i R_j$

*kolesar_3bs_01_0514, “Loss budgeting for 400GbE channels”

224Gb/s PAM4 CD tolerance

Table 1

Parameter	Value
Zero dispersion wavelength*	1300nm – 1324nm
Dispersion slope	0.092 $\frac{ps}{nm^2.km}$
PMD	0.2 $\frac{ps}{\sqrt{km}}$
Target distance	2 km

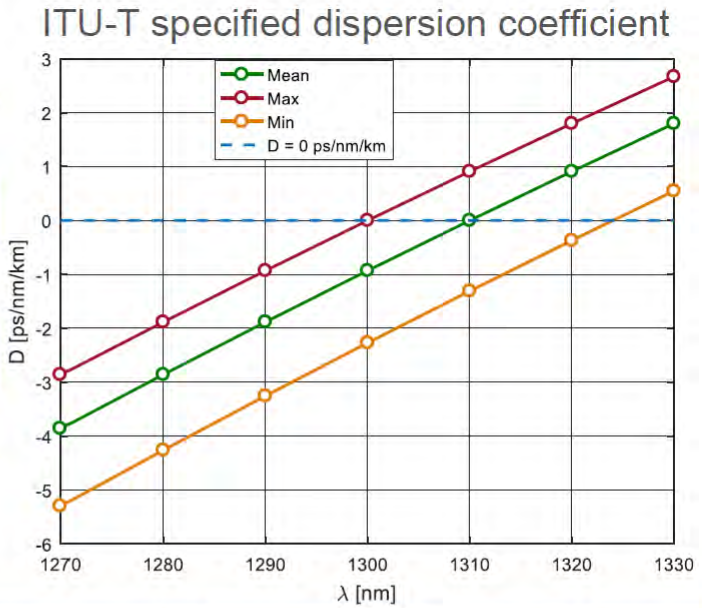
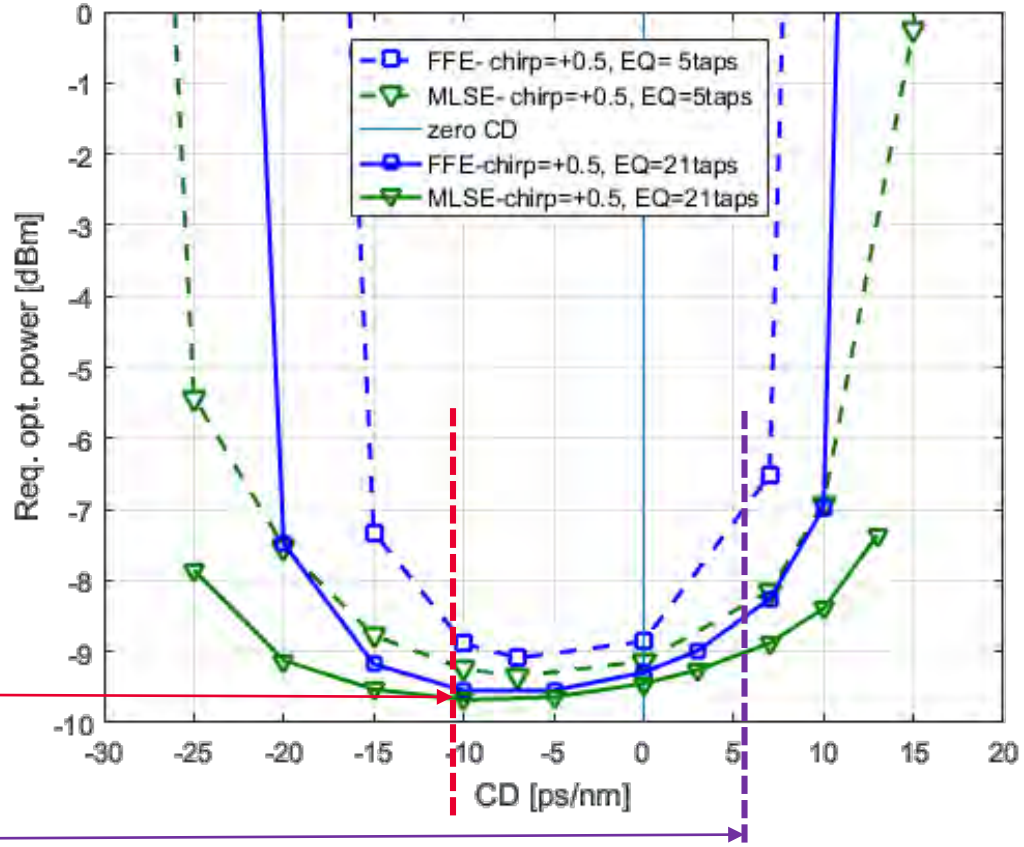


Table 2

Wavelength [nm]	1270	1290	1310	1330
Accumulated CD (Min) [ps/nm]	-10.49	-6.38	-2.45	1.29
Accumulated CD (Mid) [ps/nm]	-7.44	-3.72	0	3.72
Accumulated CD (Max) [ps/nm]	-5.58	-1.69	2.02	5.57

Numerical study



➔ It is likely that a 5 tap FFE equalizer is not sufficiently long in such case

Conclusions

- Despite the limited Tx bandwidth PAM4 was shown to offer superior performance compared to PAM6 for the EML
- This gap is expected to widen on more product-ready hardware
- PAM6 cannot fulfill triple link connectivity due to high MPI penalty and thus would have severe limitations in the 2km FR4 use case
- Modifications to the reference equalizer are likely necessary for 4x200G CWDM4 PAM4 due to the CD penalty
- Overall, simulations and measurements show that 200G/lane optical using PAM4 is a feasible technology

Thank you.