Further analysis of 8*50G PAM4 for 10km SMF

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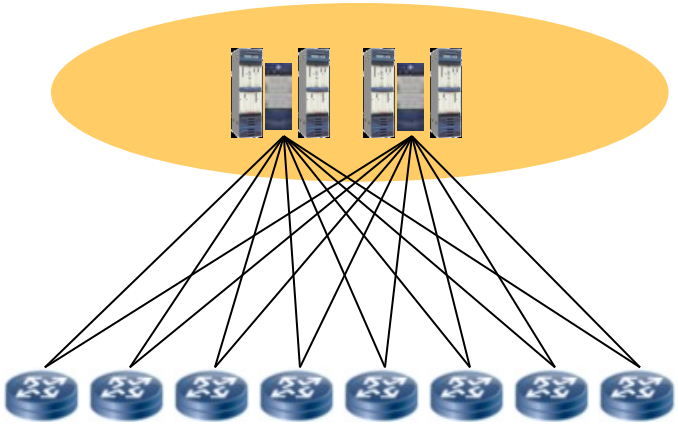
Background

- At the last meeting in May 2014 in Norfolk we presented our test results on 8*50G PAM4. We got very good feedback and also questions for further study.
- After that meeting we further investigated TDP & MPI effects and also applied more realistic signal pattern (SSPR instead of PRBS15).
- This presentation shows our test results and system analysis. All conclusions are based on KP4 FEC only.
- At the end of this presentation we will demonstrate that a 8*50G PAM4 configuration can be a suitable solution for 10km SMF applications.

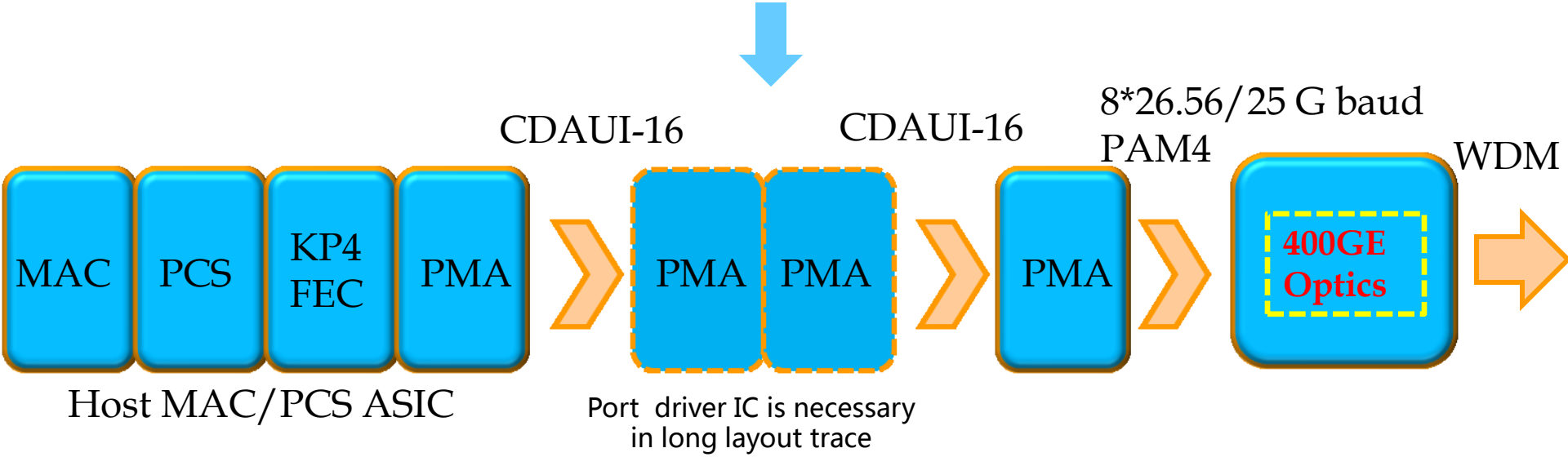
10km transmission Scenarios

Core Router-Core Router/ Core Router - OTN

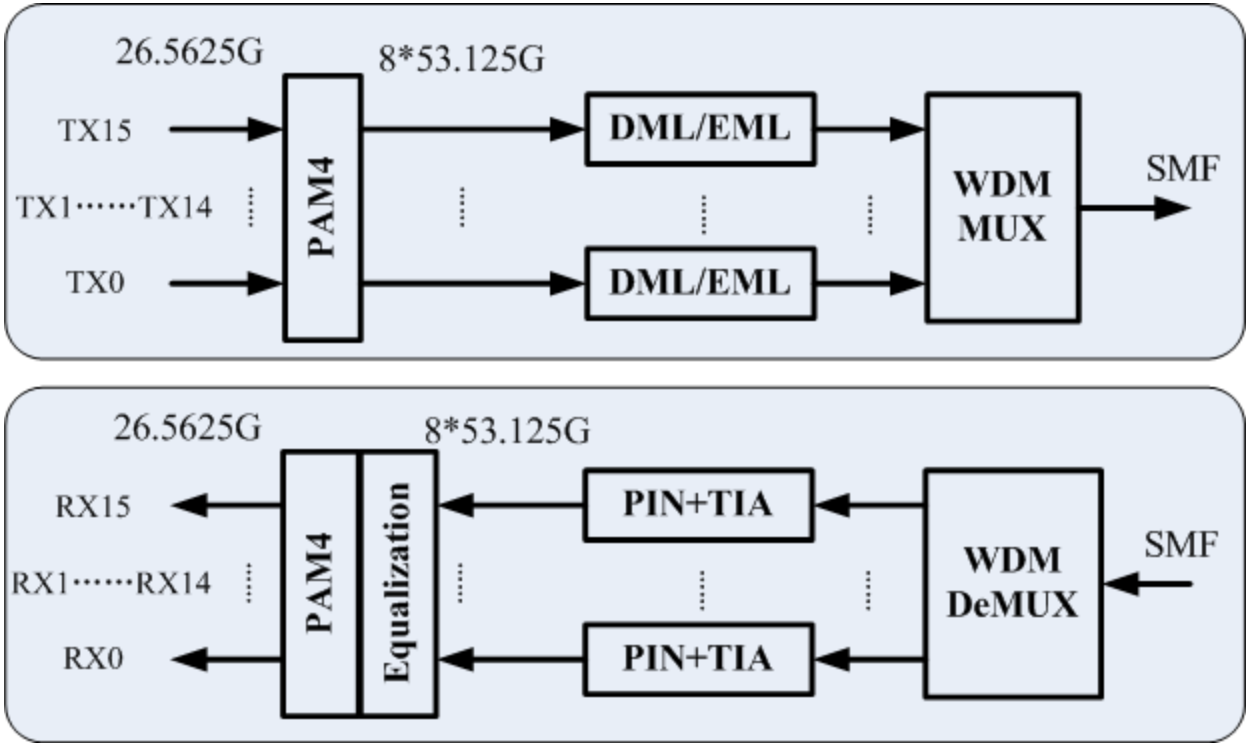


Convergence Layer

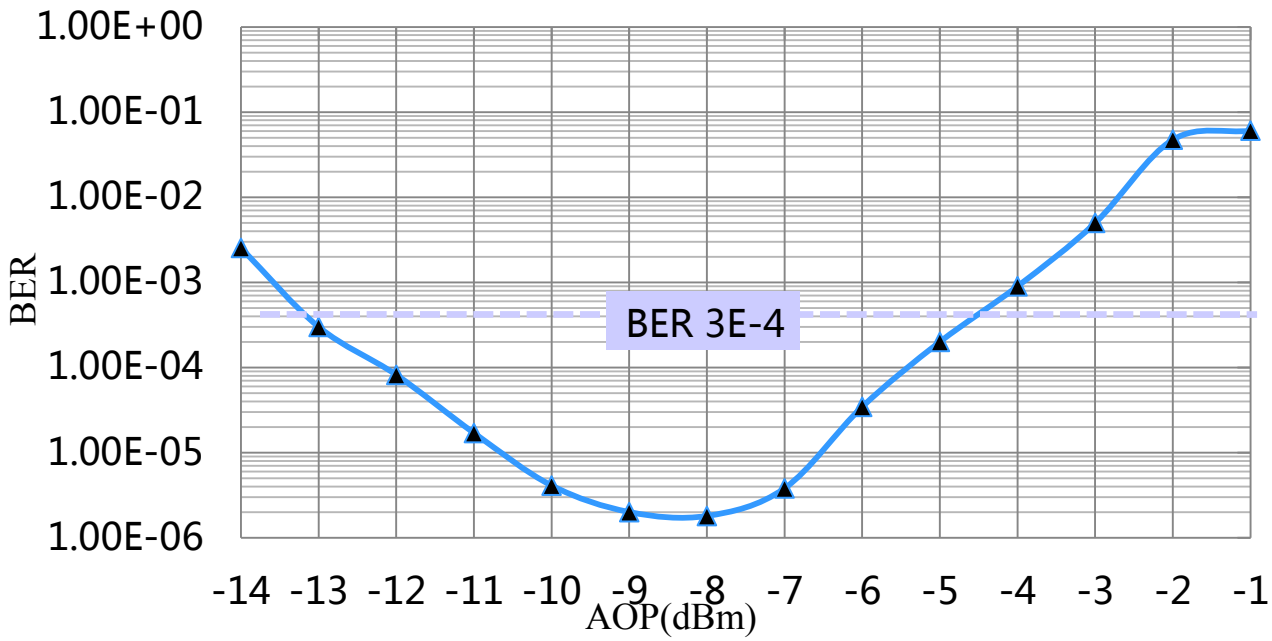
IDC



400G Optics


26.5625G
8*53.125G
TX15
TX1……TX14
TX0
PAM4
DML/EML
DML/EML
WDM MUX
SMF
26.5625G
8*53.125G
RX15
RX1……RX14
RX0
PAM4
Equalization
PIN+TIA
PIN+TIA
WDM DeMUX
SMF

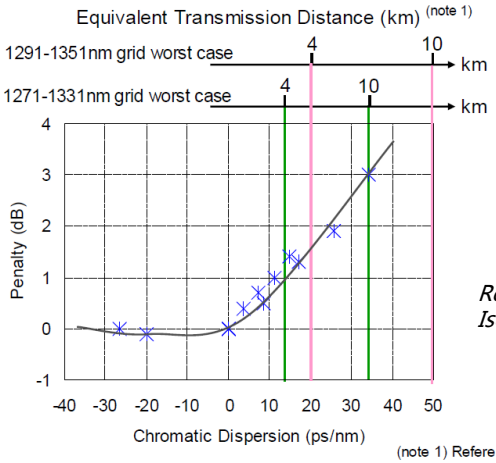
BER Test Result



- The dynamic range (and especially the overload) is limited due to the usage of a limiting TIA in the ROSA.
- With a linear TIA the dynamic range can be extended and the overload increased.
- Tested Bit Pattern: PRBS15
- Tested Bit Rate: 53.12Gb/s

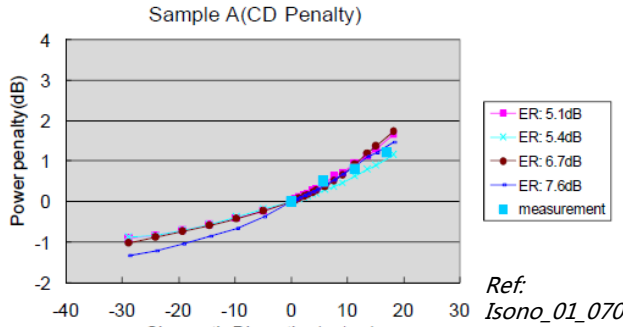
TDP – Analysis of Chromatic Dispersion Penalty

- Having looked at results from the studies during the BA project, in particular to isono_01_1107 and isono_01_0708, we note that the chromatic dispersion penalty is flattening out (or even approaching zero) for negative chromatic dispersion values up to -30ps/nm.
- We therefore use Option 3 from xu_3bs_01a_0514 as a first wavelength set for our investigations and testing.

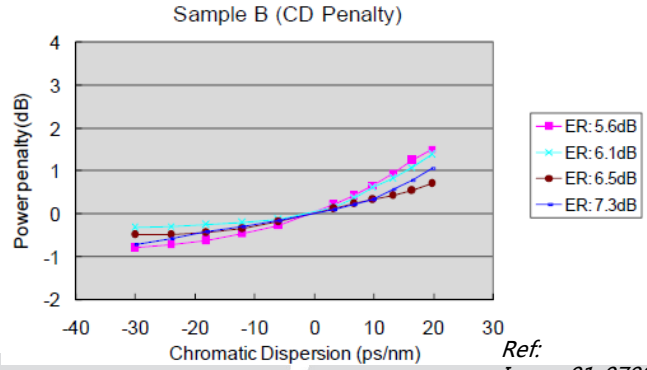


Ref: Isono_01_1107.pdf

(note 1) Reference: traverso_01_0907.pdf



Ref: Isono_01_0708.pdf



Ref: Isono_01_0708.pdf

TDP – Analysis of Chromatic Dispersion Penalty

Nominal Wavelength [nm]	Lower Limit Wavelength Range [nm]	Upper Limit Wavelength Range [nm]
1286.66 ↑	1285.65	1287.68
1291.10 ↑	1290.07	1292.12
1295.56	1294.53	1296.59
1300.05	1299.02	1301.09
1304.58	1303.54	1305.63
1309.14	1308.09	1310.19
1313.73 ↓	1312.67	1314.79
1318.35 ↓	1317.28	1319.42

Nominal Wavelength [nm]	Lower Limit Wavelength Range [nm]	Upper Limit Wavelength Range [nm]
1295.56	1294.53	1296.59
1300.05	1299.02	1301.09
1304.58	1303.54	1305.63
1309.14	1308.09	1310.19
1313.73 ↓	1312.67	1314.79
1318.35 ↓	1317.28	1319.42
1323.00 ↓	1321.93	1324.08
1327.69 ↓	1326.61	1328.77

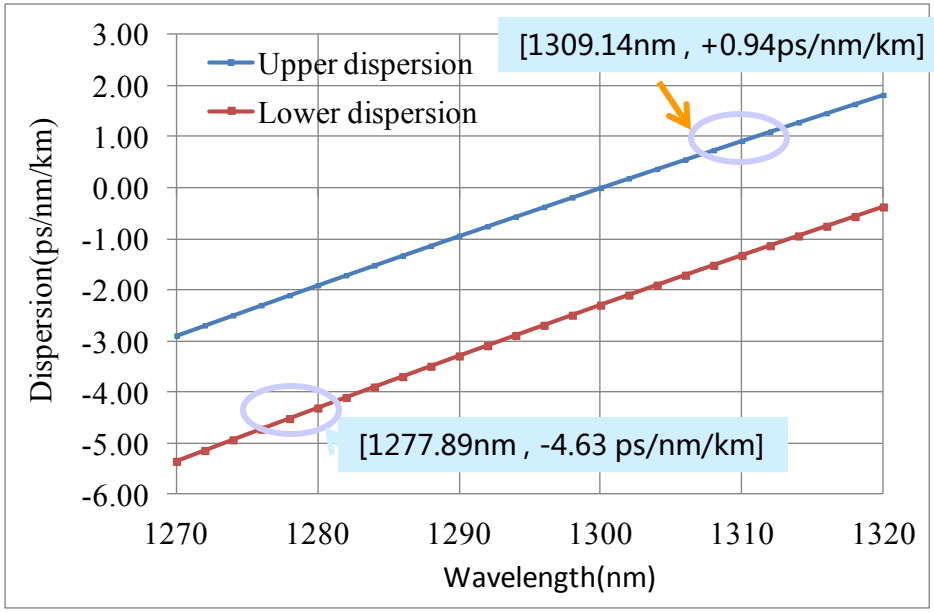
Nominal Wavelength [nm]	Lower Limit Wavelength Range [nm]	Upper Limit Wavelength Range [nm]
1277.89 ↑	1276.89	1278.89
1282.26 ↑	1281.25	1283.27
1286.66 ↑	1285.65	1287.68
1291.10 ↑	1290.07	1292.12
1295.56	1294.53	1296.59
1300.05	1299.02	1301.09
1304.58	1303.54	1305.63
1309.14	1308.09	1310.19

Nominal Wavelength [nm]	Lower Limit Wavelength Range [nm]	Upper Limit Wavelength Range [nm]
1295.56	1294.53	1296.59
1297.80	1296.77	1298.84
1300.05	1299.02	1301.09
1302.31	1301.27	1303.35
1304.58	1303.54	1305.63
1306.85	1305.81	1307.90
1309.14	1308.09	1310.19
1311.43	1310.37	1312.48

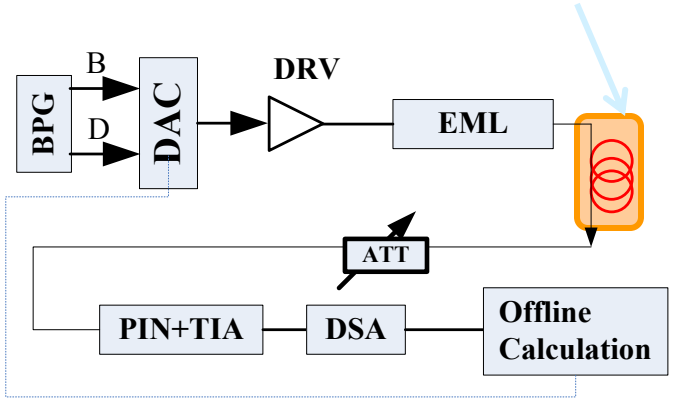
- For wavelength set Option 3 the lowest negative dispersion is -46.3ps/nm and highest positive dispersion is +9.4ps/nm, the latter the same as for LR4 (*1)

Note1. Ref: cole_01_0608.pdf

TDP – Analysis of Chromatic Dispersion Penalty

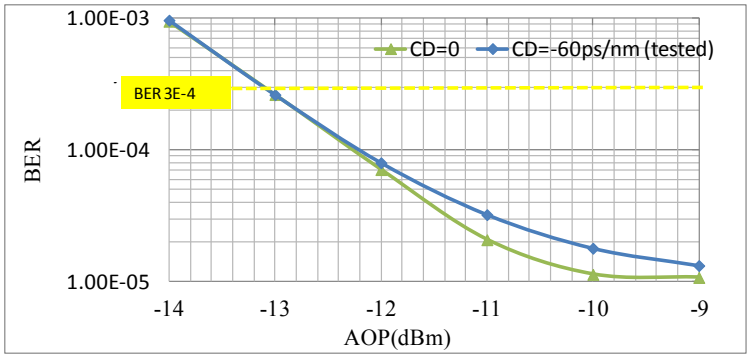


Test fiber characteristics: -60 ps/nm @1310nm.
Length 1km.

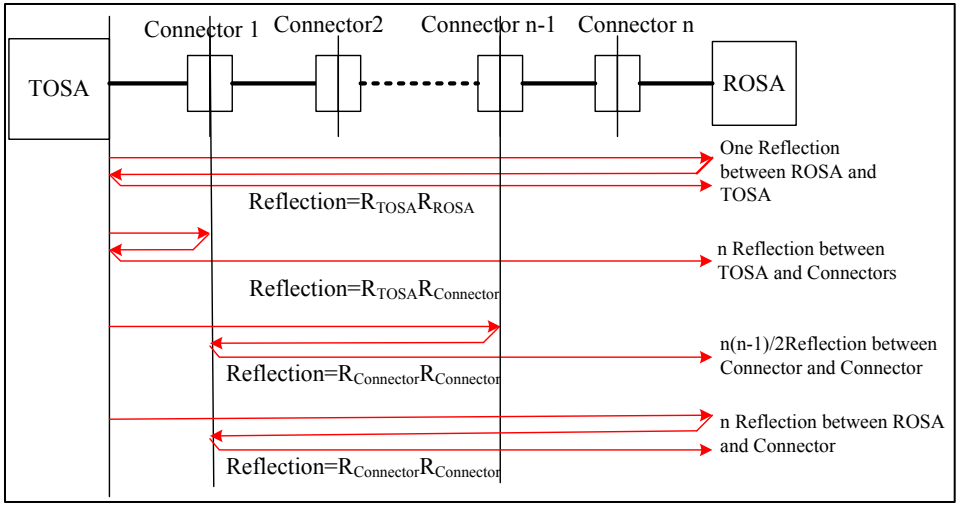


Fiber No	Type	Length	ATT1310	Disp1310
N5Y*******2	PM1310 125-13/250	1 Km	1.03 dB	-61 ps/nm

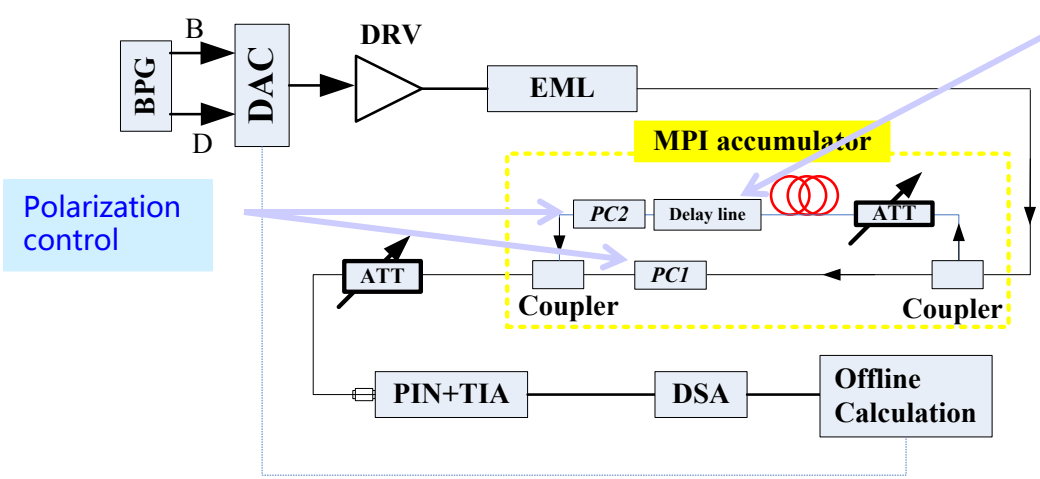
- Our tests are based on EML transmitters and we have first focused on testing the CD penalty for -60ps/nm.
- Reconfirming existing LR4 results for +10ps/nm and checking the CD penalty for DML lasers will be done asap.
- Our test shows a CD penalty of nearly 0dB for a chromatic dispersion of -60ps/nm.



Investigation impact MPI – Test Setup

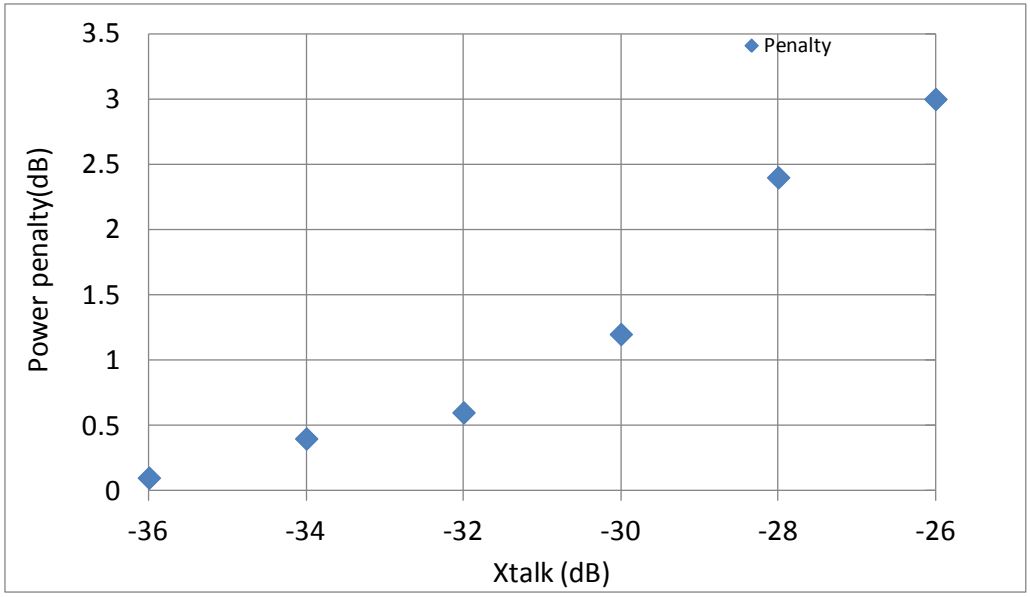


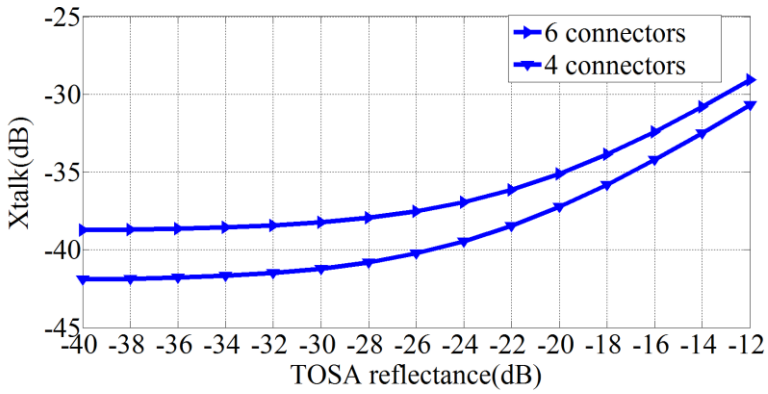
Ref:
Farhood_01_1112_optx.pdf



Worst case:
1. **Phase alignment;**
2. **Polarization alignment;**

Investigation impact MPI – Test Results

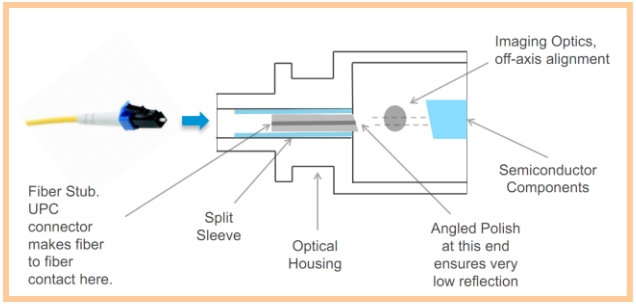




Conditions:
Phase alignment;
Polarization alignment;
Connector reflectance: -26 dB
Rx reflectance: -26 dB
Tx reflectance: [-12 -30] dB

- Under condition of 4 connectors (each -26dB), maximum MPI Xtalk is around -30.2dB.
- Then the power penalty is about 1.2dB@3e-4.
- If channel has max return loss 21dB, then 2 connectors @-26dB and 1 connector @-33.9dB reflectance. In this case, MPI penalty will be lower.

Possible Improvement



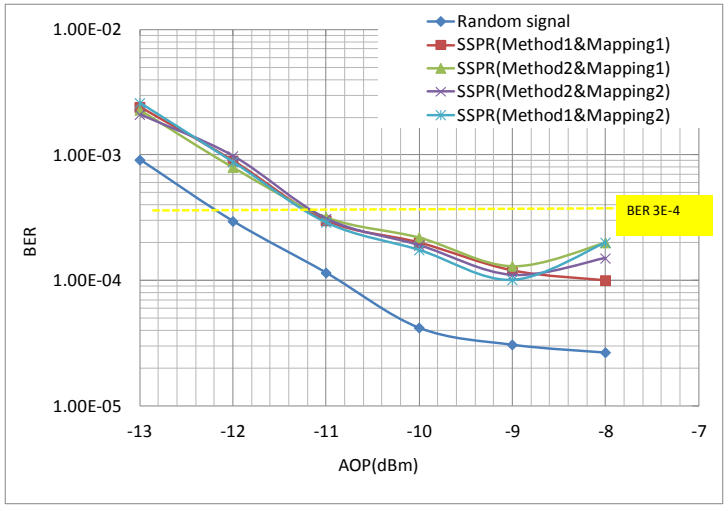
Ref: Bhatt_01_0512_optx.pdf

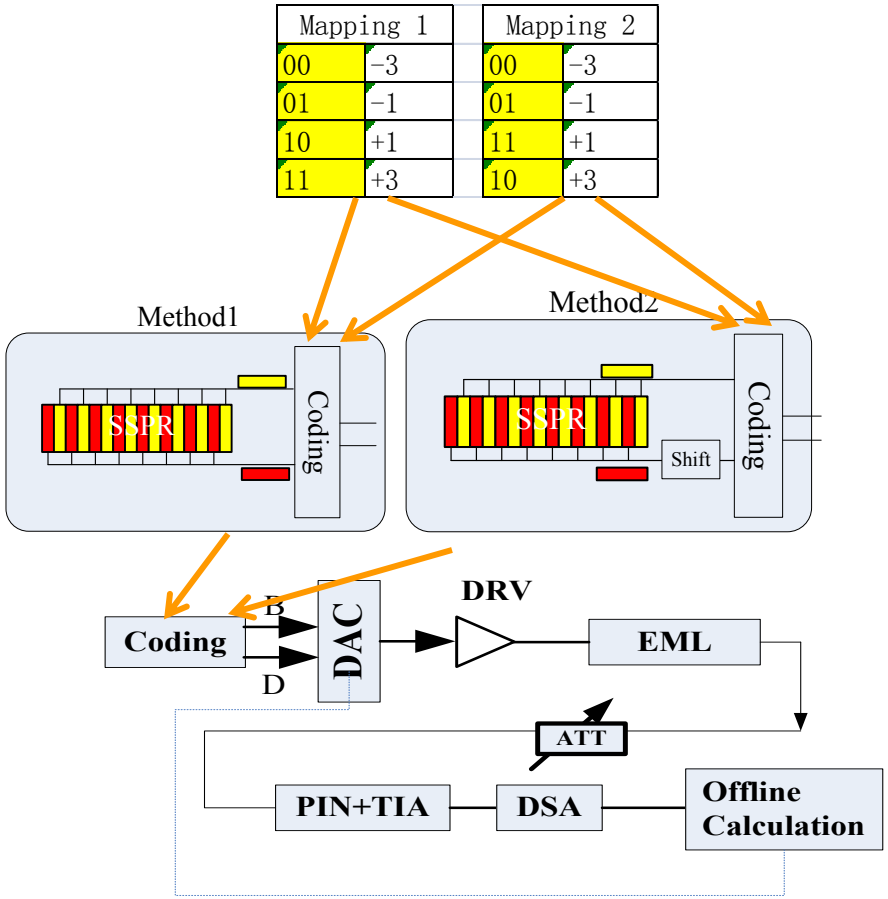
SSPR test instead of PRBS 2^{15}

PRBS28 Seed=0080080	CID 1, 72 x 0	PRBS28 Seed=FFFFFFF	PRBS28 Seed=0080080 Diff encoded	$\overline{\text{PRBS28}}$ Seed=0080080	$\overline{\text{CID}}$ 0, 72 x 1	$\overline{\text{PRBS28}}$ Seed=FFFFFFF	$\overline{\text{PRBS28}}$ Seed=0080080 Diff encoded
5437 bits	73 bits	5437 bits	5434 bits	5437 bits	73 bits	5437 bits	5434 bits

- Total length 32,762 bits
- All 2^28-1 PRBS28 sequences are generated using taps 25 and 28
- Block 1 is 5437 bits of PRBS28 seed = 0x0080080 and begins with 8 x 0, 1, 11 x 0, 1, 12 x 0, 1 …
- Block 2 is 1 followed by 72 x 0
- Block 3 is 5437 bits of PRBS28 seed = 0xFFFFFFFF and begins 28 x 1, 25 x 0, 3 x 1, 22 x 0 …
- Block 4 takes the same sequence as block 1 (omitting the last 3 bits) and codes it:
  - A zero is encoded as a change of output
  - A one is encoded as no change of output
  - The output before the first bit is assumed to have been a 0
  - This block begins 10101010010101010101101010101011011010 …
- Blocks 5 to 8 are the inverse of 1 to 4

Ref: CEI Short Stress Patterns White Paper





- Our test results: Using SSPR will induce about 1 dB power penalty @ 3e-4 compared with PRBS15 pattern test.

Power Budget Analysis

	HW test	Potential specification	Unit
Tx OMA (01-00) min Tested	-1.8	–	dBm
Tx OMA (01-00) min Specification Value	–	-6	dBm
Max TDP	?	?	dB
Tx OMA (01-00) – TDP min	-2.8	-7	dBm
Channel insertion loss Specification Value	–	6	dB
Rx ROP OMA (01-00) with KP4 FEC Specification Value	–	-13	dBm
Rx ROP OMA (01-00) with KP4 FEC Tested	-13	–	dBm
Available channel loss	**10.2**	–	dB

Summary

- Test results
  - The Chromatic Dispersion penalty has been investigated for a specific wavelength set and the penalty is almost zero for down to -60ps/nm dispersion.
  - An MPI penalty of 1.2dB may occur under some conditions, which may be worse than under realistic specification conditions.
  - We also performed BER testing using an SSPR test pattern which is a much more realistic test condition than PRBS 2^{15}.
  - We have demonstrated that a 8*50G PAM4 configuration can be a suitable solution for 10km SMF applications.
- Future work
  - Confirm minimum impact of MPI under practical channel conditions and investigate improvement of transmitter return loss.
  - Improve receiver operating range by using a linear TIA.
  - Test CD penalty for positive dispersion to establish suitable wavelength set.
  - Work on relevant topics that will be identified during San Diego meeting.
  - We invite any company who is interested in the study of PAM4 to join us to confirm and/or improve our test results towards the generation of a base-line power budget.

Thank You