Investigation of the technical feasibility for 200G/400G beyond 10km optical PHYs using high-power TOSA and APD-ROSA

Shuto Yamamoto, Toshihide Yoshimatsu,
NTT Corporation

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Overview

Feasibility investigation for 200G/400G beyond 10km optical PMD

- 53-Gb/s and 56-Gb/s PAM4 transmission experiments with high-power TOSA and APD-ROSA
- Receiver sensitivity and dispersion penalty are evaluated assuming 8-lane LAN-WDM 40-km transmission.

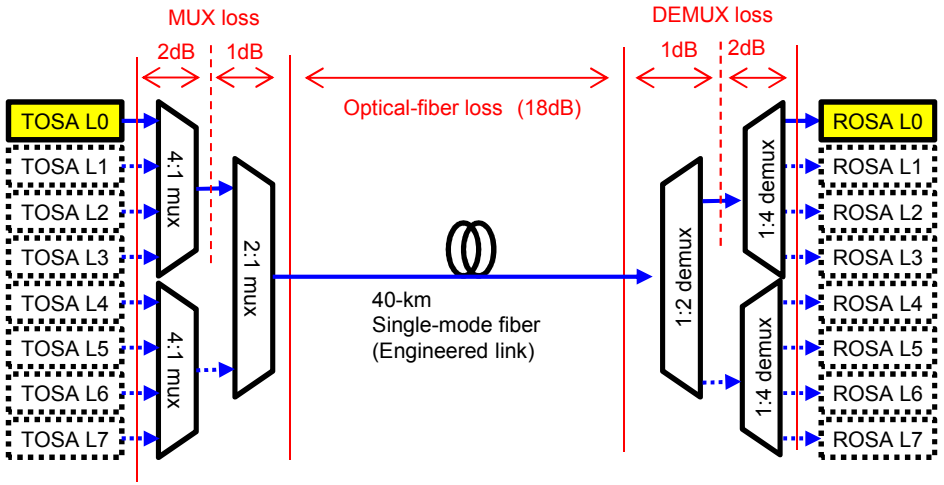
In Orlando meeting, …
investigation using normal EML + APD was reported. (sone_b10k_01a_1117)

In this meeting, …
investigation using high-power EML + APD is reported.

Assumed link budget for 50G/200G/400G 40km

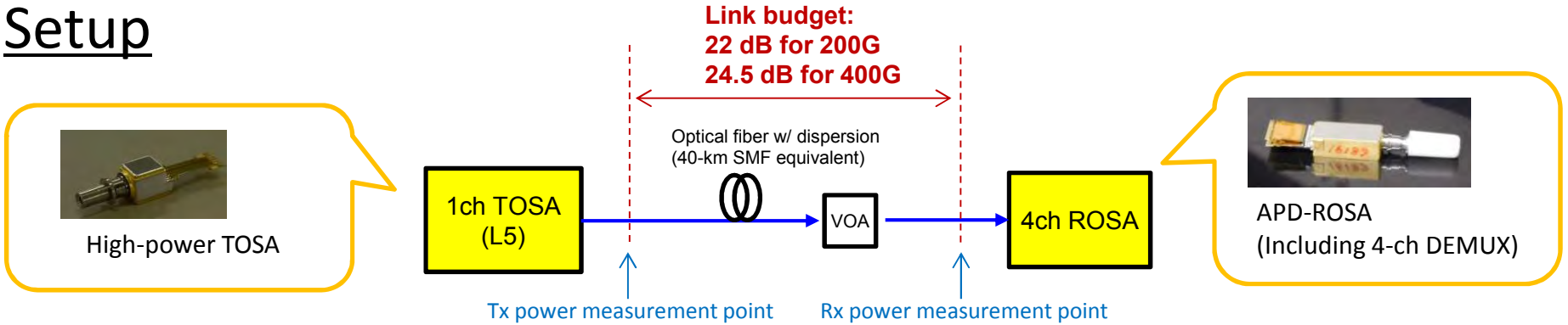
	50G 40km	200G 40km	400G 40km
Optical fiber * Engineered link	18	18	18
MUX	0	2 (4-ch MUX)	3 (8-ch MUX)
DEMUX	0	2 (4-ch DEMUX)	3 (8-ch DEMUX)
Dispersion penalty	0.5	0.5 (Worst CH)	1 (Worst CH)
MPI penalty	0.5	0.5	0.5
Other	1	1	1
Total	20 dB	24 dB	26.5 dB

Configuration of 8-lane LAN-WDM

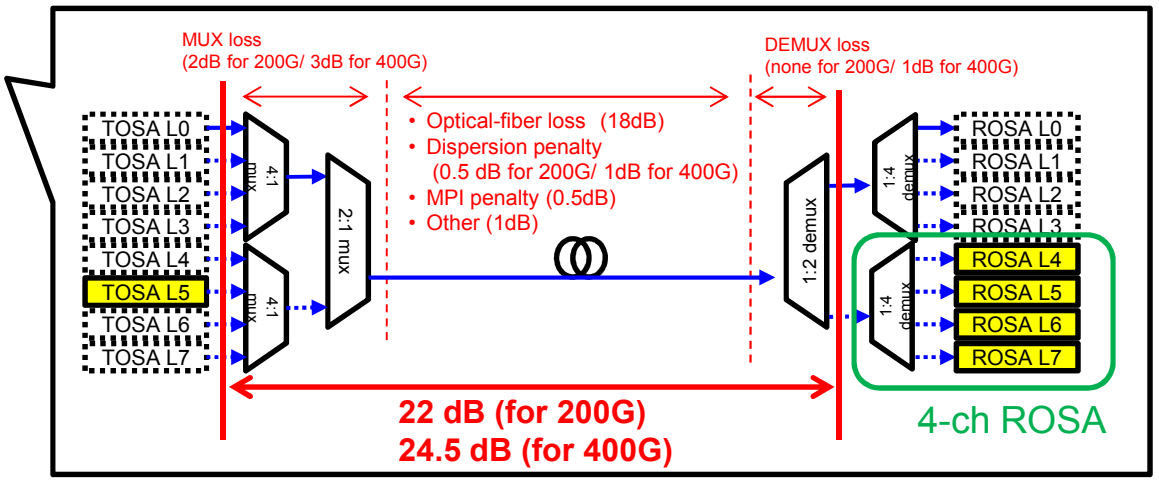


Experimental setup

Setup



- PAM4 signal is transmitted using 1-ch high-power TOSA and 4-ch APD-ROSA.
- Receiver sensitivity and dispersion penalty are evaluated assuming 8-lane LAN-WDM 40-km transmission.
- In the case with 4-ch ROSA including 4-ch DEMUX, the link budget is below;
  - 200G: 24 dB → 22 dB
  - 400G: 26.5 dB → 24.5 dB



Experimental result (53-Gb/s PAM4)

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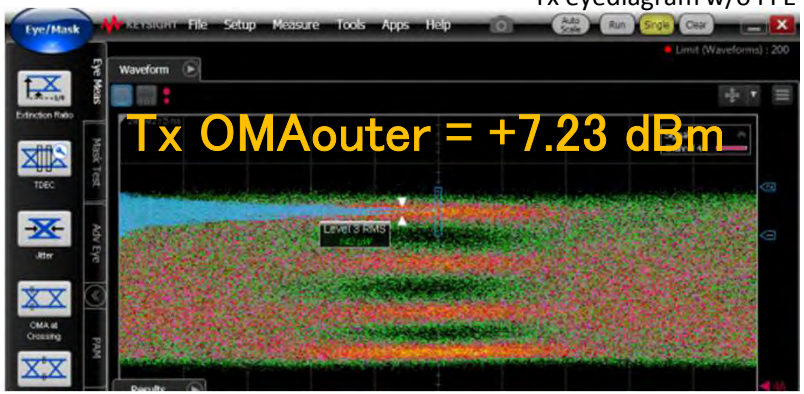
1ch TOSA performance

*Tx eyediagram w/o FFE

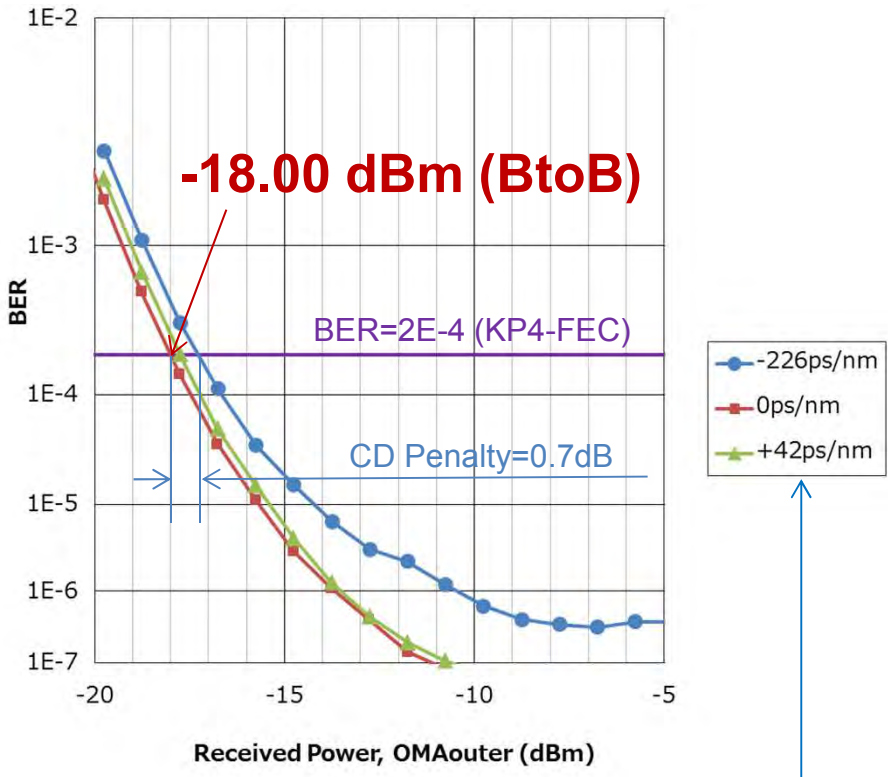


PRBS31, 1299.187nm, ER=7dB, TEC=45degC

Link budget
= 25.2dB

	200G 40 km	400G 40 km
Required	22 dB	24.5 dB
Measured	25.2 dB	
Margin	3.2 dB	0.7 dB

4ch APD-ROSA performance

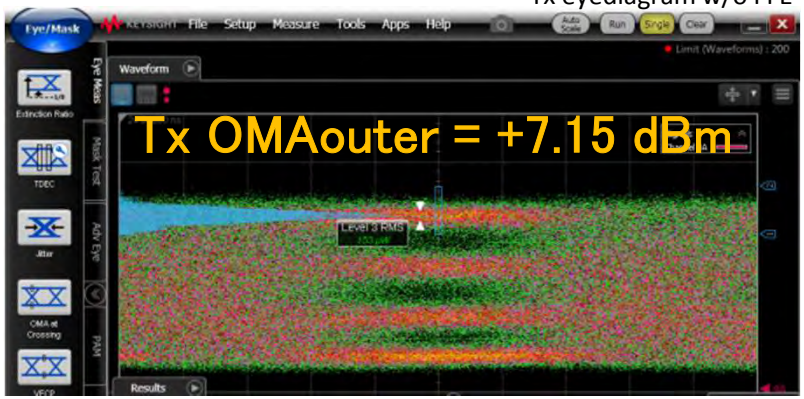


In 8-lane LAN-WDM 40-km transmission, the range of chromatic dispersion is from -203.3 to +37.5 ps/nm.

Experimental result (56-Gb/s PAM4)

1ch TOSA performance

*Tx eyediagram w/o FFE

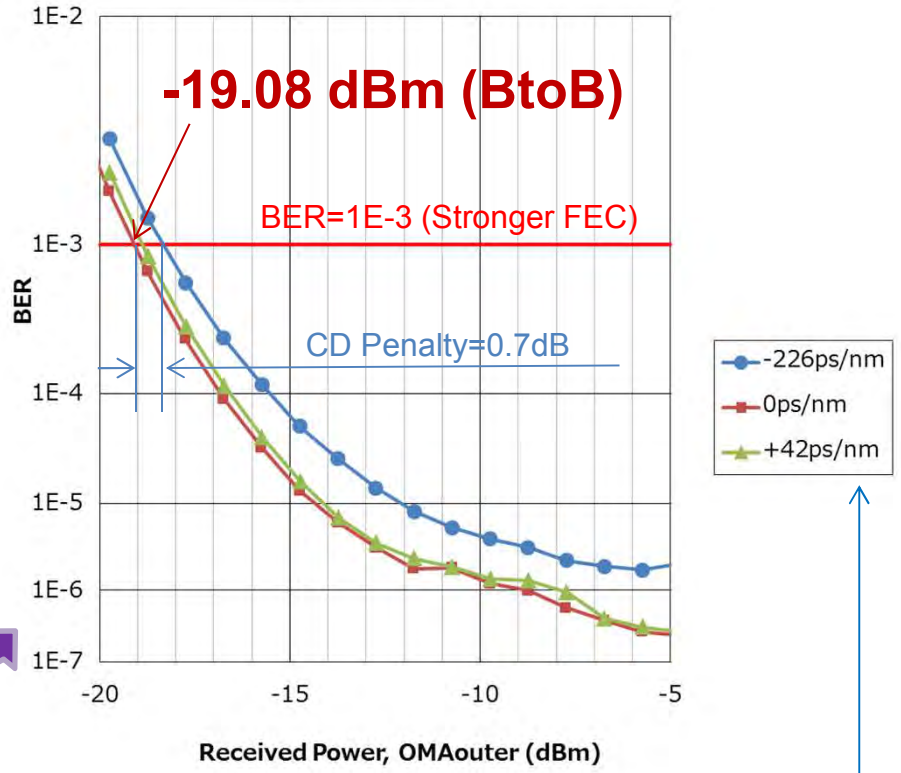


PRBS31, 1299.187nm, ER=7dB, TEC=45degC

Link budget = 26.2dB

	200G 40 km	400G 40 km
Required	22 dB	24.5 dB
Measured	26.2 dB	
Margin	4.2 dB	1.7 dB

4ch APD-ROSA performance



In 8-lane LAN-WDM 40-km transmission, the range of chromatic dispersion is from -203.3 to +37.5 ps/nm.

Stronger FEC

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Summary of RS FEC Options Considered

RS FEC(n,k,t,m)	CG	NCG*	BERin	Overhead	SerDes Rate	Block Time	Latency**	Area Ratio
Group 1 : Similar RS FEC as KR4 FEC								
RS(528,514,7,10)	5.39	5.28	3.92E-05	0%	25.78125	51.2ns	~87ns	1X
RS(544,514,15,10)	6.64	6.39	3.09E-04	3.03%	26.5625	51.2ns	~112ns	2.9X
RS(560,514,23,10)	7.3	6.93	7.60E-04	6.06%	27.34375	51.2ns	~208ns	14.5X
RS(576,514,31,10)	7.76	7.26	1.30E-03	9.09%	28.125	51.2ns	~258ns	33.4X
Group 2 : Large Block RS FEC								
RS(1056,1028,14,11)	6.07	5.95	1.29E-04	0%	25.78125	102.4ns	~172ns	2.6X
RS(1088,1028,30,11)	7.12	6.88	6.06E-04	3.03%	26.5625	102.4ns	~315ns	16.7X
RS(1120,1028,46,11)	7.7	7.33	1.20E-03	6.06%	27.34375	102.4ns	~414ns	54.8X
RS(1152,1028,62,11)	8.11	7.61	1.90E-03	9.09%	28.125	102.4ns	~514ns	129.5X
Group 3 : RS(255,239) Like RS FEC								
RS(255,239,8,8)	6.12	5.83	1.39E-04	6.7%	27.5	18.9ns	~49ns	1.1X
RS(510,478,16,9)	6.85	6.57	4.21E-04	6.7%	27.5	42.5ns	~162ns	5.3X
RS(1020,956,32,10)	7.34	7.06	7.95E-04	6.7%	27.5	93.1ns	~304ns	27.2X
Group 4 : 256/257b coding friendly RS FEC***								
RS(800,771,14,10)	6.29	6.13	1.83E-04	1.01%	26.04	76.8ns	~140ns	2.6X
RS(816,771,22,10)	6.95	6.71	4.84E-04	3.03%	26.5625	76.8ns	~232ns	9.4X
RS(840,771,34,10)	7.58	7.22	1.10E-03	6.06%	27.34375	76.8ns	~306ns	30.6X
RS(864,771,46,10)	8.02	7.53	1.80E-03	9.09%	28.125	76.8ns	~379ns	72.1X

Ref.) wang_x_3bs_01a_0115

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Conclusion

- We investigate the feasibility of 200G/400G 40km optical PMD through the experiment using high-power TOSA & APD-ROSA.
- 200G/400G 40km transmissions have some margins.

	OMA margin	
	53 Gb/s (KP4-FEC)	56 Gb/s (Stronger FEC)
200G 40km	3.2 dB	4.2 dB
400G 40km	0.7 dB	1.7 dB

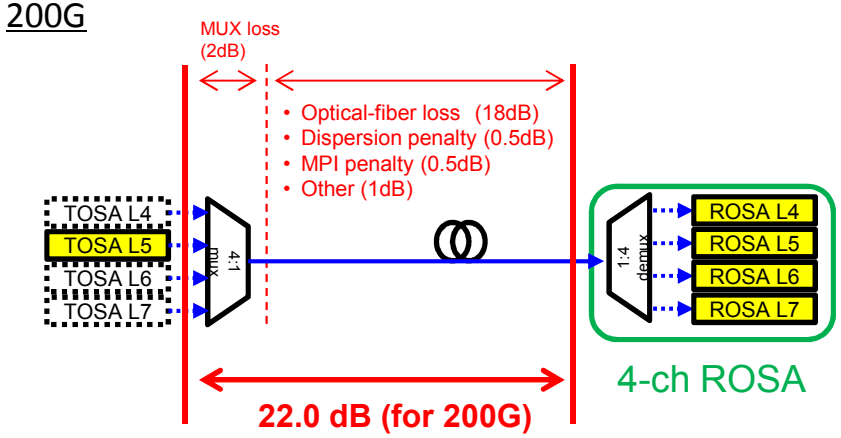
1-dB improvement

Backup

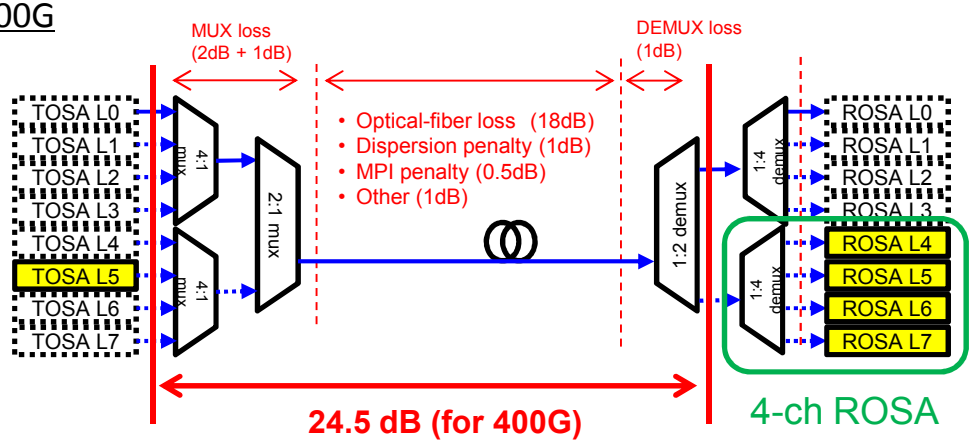
Required link budget in this investigation

	200G 40km	400G 40km
Optical fiber * Engineered link	18	18
MUX	2 (4:1 MUX)	3 (4:1 MUX & 2:1 MUX)
DEMUX	-	1 (1:2 DEMUX)
Dispersion penalty	0.5 (Worst CH)	1 (Worst CH)
MPI penalty	0.5	0.5
Other	1	1
Total	22 dB	24.5 dB

200G

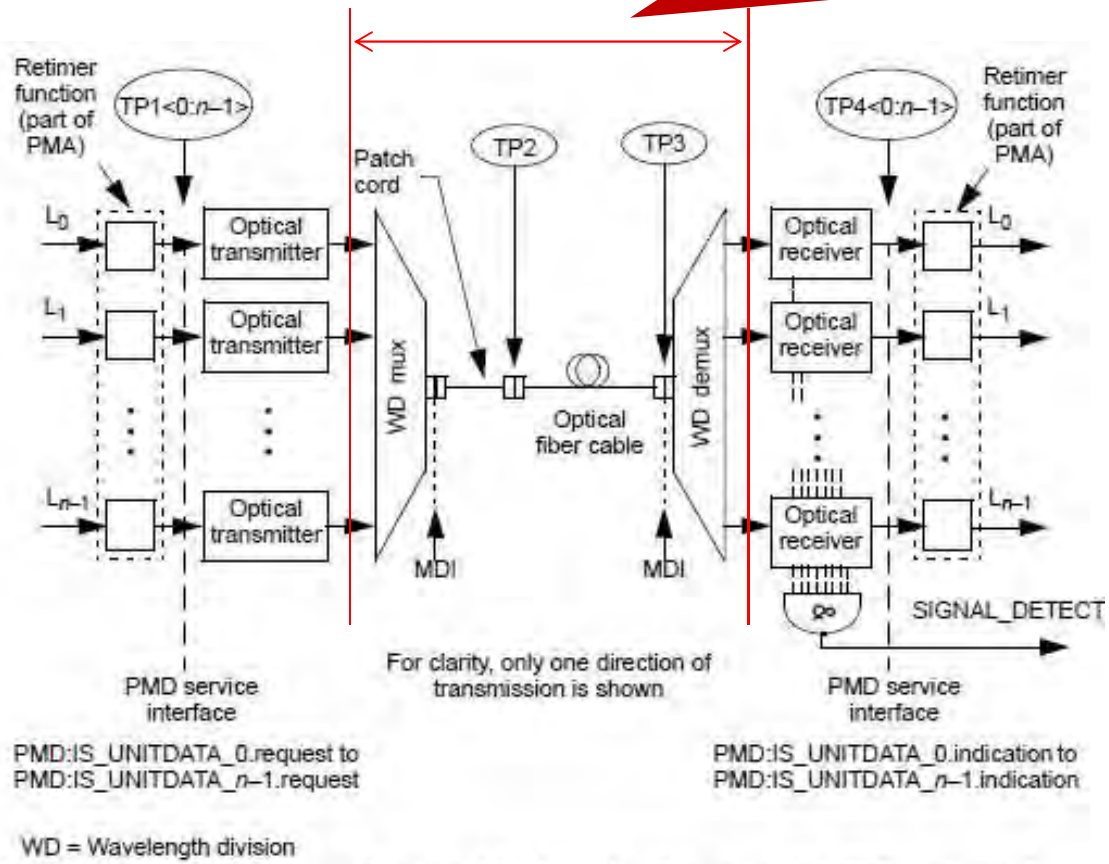


400G



Block diagram

Link budget is defined from optical transmitter to optical receiver in our investigation.



NOTE—Specification of the retimer function and the electrical implementation of the PMD service interface is beyond the scope of this standard.

Figure 122–2—Block diagram for 200GBASE-FR4, 200GBASE-LR4, 400GBASE-FR8, and 400GBASE-LR8 transmit/receive paths

Chromatic-dispersion penalty

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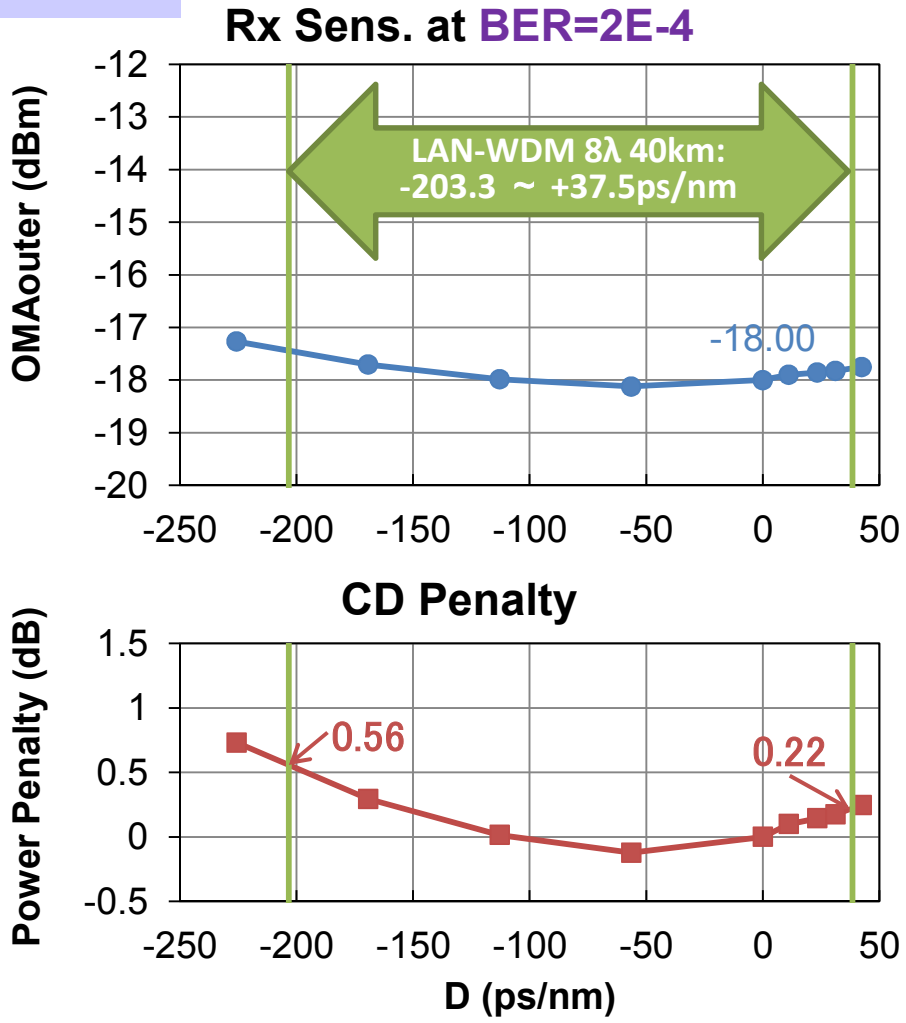
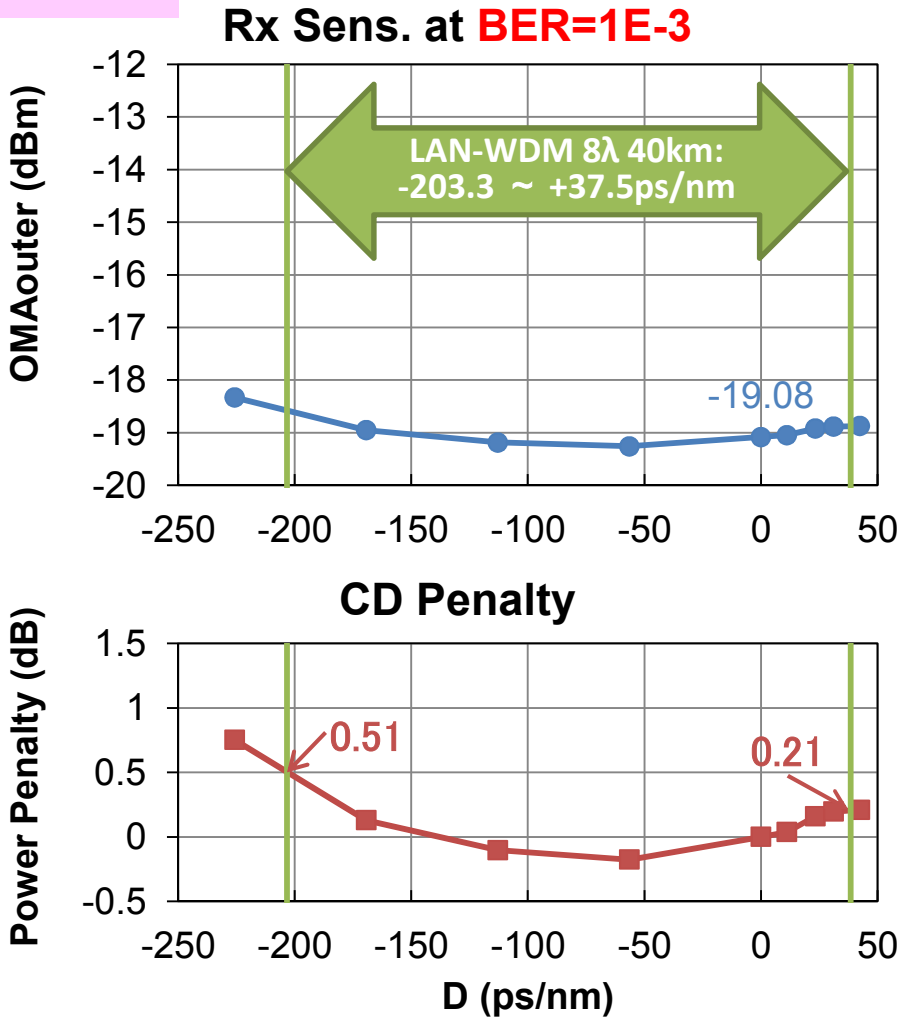
26GBd



CD penalty ≦ 0.56dB (-203.3 ~ +37.5ps/nm)

28GBd



CD penalty ≦ 0.51dB (-203.3 ~ +37.5ps/nm)

Worst-case dispersion for 40-km SMF transmission

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Worst-case dispersion for SMF transmission

- Negative dispersion

$0.93 \cdot \lambda \cdot [1-(1324/\lambda)^4] = -203.3$ ps/nm

- Positive dispersion

$0.93 \cdot \lambda \cdot [1-(1300/\lambda)^4] = +37.5$ ps/nm

4 x LR8-value

Table 123–5—Wavelength-division-multiplexed lane assignments

Lane	Center frequency	Center wavelength	Wavelength range
L_0	235.4 THz	1273.54 nm	1272.53 to 1274.54 nm
L_1	234.6 THz	1277.89 nm	1276.89 to 1278.89 nm
L_2	233.8 THz	1282.26 nm	1281.25 to 1283.27 nm
L_3	233 THz	1286.66 nm	1285.65 to 1287.68 nm
L_4	231.4 THz	1295.56 nm	1294.53 to 1296.59 nm
L_5	230.6 THz	1300.05 nm	1299.02 to 1301.09 nm
L_6	229.8 THz	1304.58 nm	1303.54 to 1305.63 nm
L_7	229 THz	1309.14 nm	1308.09 to 1310.19 nm

Table 123–12—Transmitter compliance channel specifications

PMD type	Dispersion[a] (ps/nm)		Insertion loss[b]	Optical return loss[c]	Max mean DGD
	Minimum	Maximum			
400GBASE-FR8	$0.0465 \cdot \lambda \cdot [1-(1324/\lambda)^4]$	$0.0465 \cdot \lambda \cdot [1-(1300/\lambda)^4]$	Minimum	19.8 dB	0.8 ps
400GBASE-LR8	$0.2325 \cdot \lambda \cdot [1-(1324/\lambda)^4]$	$0.2325 \cdot \lambda \cdot [1-(1300/\lambda)^4]$	Minimum	17.6 dB	0.8 ps

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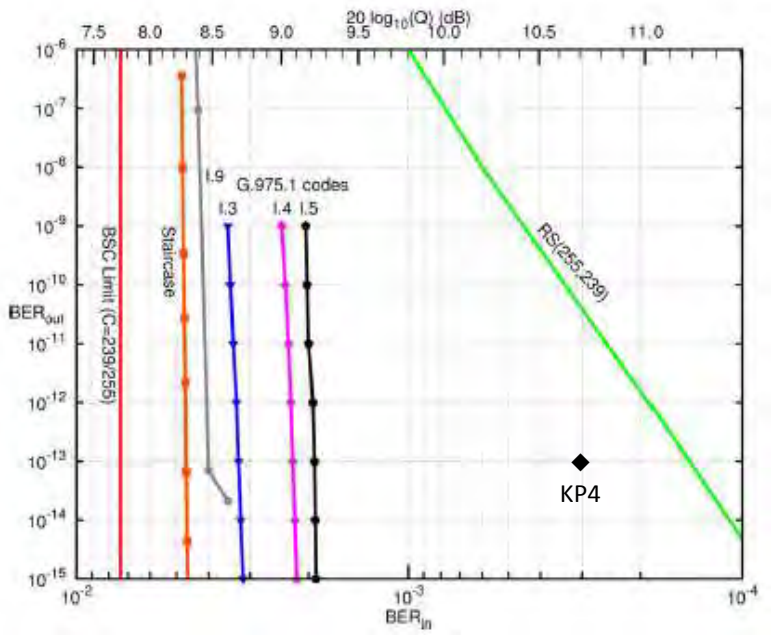
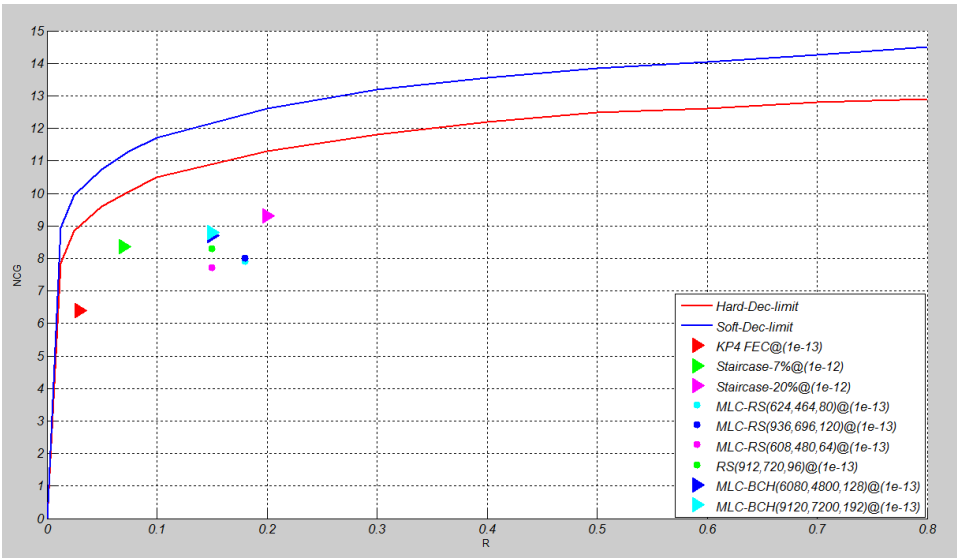
Beyond 10km: stronger FEC

- Several potential hard-decision FEC with 8-9 dB NGC can help to achieve beyond 10km 400GbE.
  - RS-FEC, BCH-FEC, or Staircase FEC…



Ref.) B. P. Smith, et al., JLT, no. 1, vol. 30 (2012)



Ref.) wang_ecdc_01_0316

400GbE 40km application

Extended reach interface is essential for inter-building connections in service providers network.

	Single-mode fiber		
Reach	2 km	10 km	40 km
Application	Intra-building Inter-building usage #1		Inter-building usage #2
802.3bs objectives	✓	✓	-

10-km reach:
Covers 50% of inter-building links
40-km reach (for example):
Covers almost 100% of inter-building links

- Low-cost solution for some metro areas