NTT

Innovative R&D by NTT

Investigation of the technical feasibility for 50G/200G/400G beyond 10km optical PHY

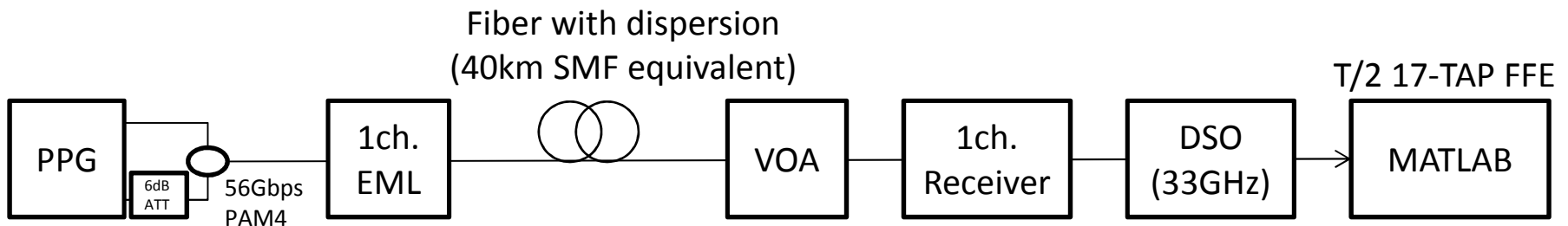Yoshiaki Sone NTT

Overview

Feasibility investigation for 50G/200GbE/400GbE beyond 10km optical PMD.

- 56Gb/s PAM4 transmission experiment with APD receiver
  -> receiver sensitivity and dispersion penalty is evaluated assuming 8-lane LAN-WDM

- Example of high power EML

56Gbps PAM4 transmission with APD

- 1ch. 56Gbps PAM4 optical transmission experiments using different EMLs and an APD receiver.
- Worst-case dispersion for 8 lambda LAN-WDM transmission over 40km SMF.

Fiber with dispersion
(40km SMF equivalent)

T/2 17-TAP FFE

| PPG | | 1ch. EML | | VOA | 1ch. Receiver | DSO (33GHz) | MATLAB |

6dB ATT 56Gbps PAM4

Tx		Fiber dispersion [ps/nm]		Rx	KP4 (limit=2E-4)		Stronger FEC(limit=1E-3 *2)	
					Rx sensitivity*1 [dBm]	CD Penalty [dB]	Rx sensitivity*1 [dBm]	CD Penalty [dB]
EML#1 ER=5.6[dB] 1304.3nm(L6)	X	-203	X	APD receiver	~ -18.0	~1.5	~ -19.1	~0.5
		0						
EML#2 ER=5.8[dB] 1308.9nm(L7)		+38						

* 1 OMA_outer, Without WDM-demux, value at zero ps/nm
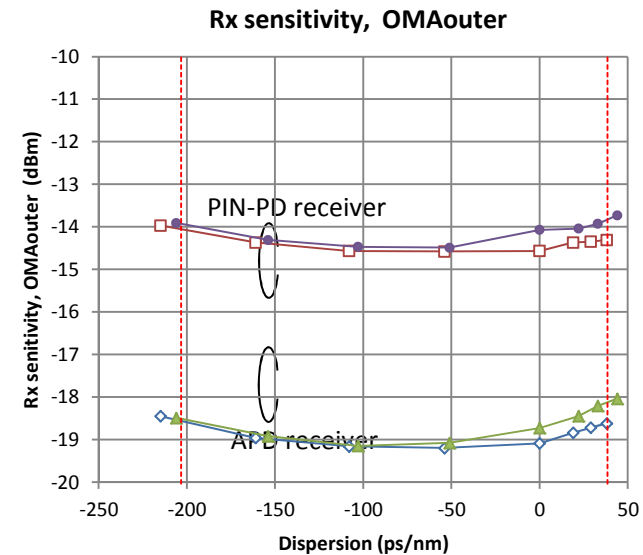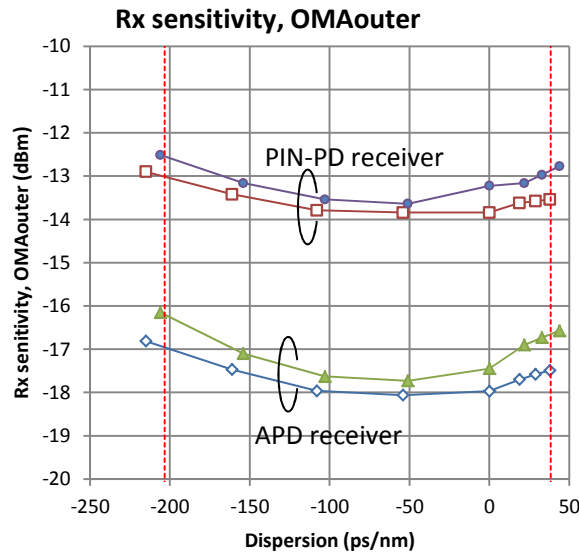* 2 BER limit assuming possible FEC(s) stronger than KP4

Evaluation results

	KP4 FEC (limit = 2E-4)	Stronger FEC (limit = 1E-3)
Min. Rx sensitivity (EML#1):	-18.0 dBm	-19.1 dBm
Min. Rx sensitivity (EML#2):	- 17.4 dBm	-18.7 dBm
CD penalty :	~ 1.5 dB	~ 0.5 dB

EML#1+APD
EML#1+PIN-PD
EML#2+APD
EML#2+pin-PD
-203.3ps/nm
+37.5ps/nm

Target dispersion
-203.3 to +38.5ps/nm

* Without 8λWDM demux loss

Rx sensitivity, OMAouter

PIN-PD receiver

APD receiver

CD penalty

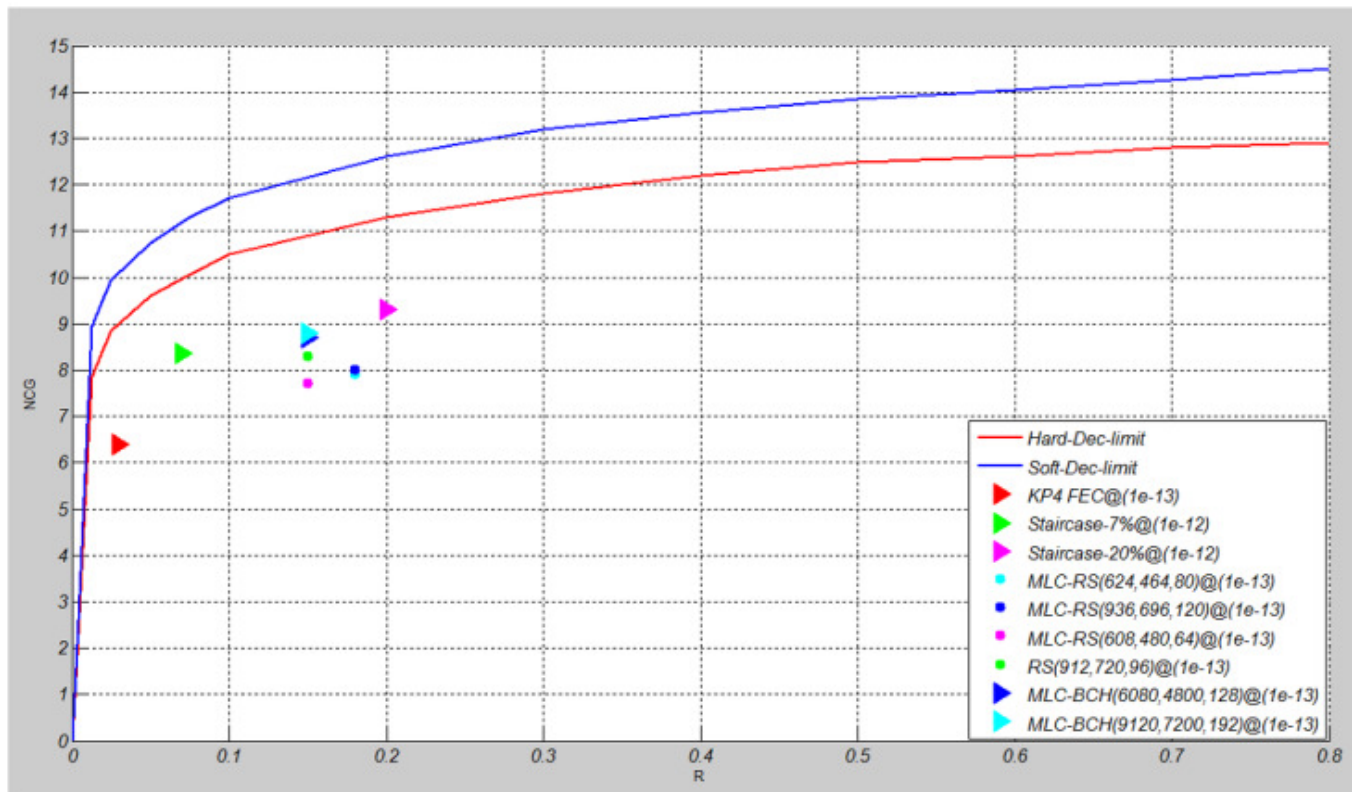**Rx sensitivity, OMAouter**

PIN-PD receiver

APD receiver

CD penalty
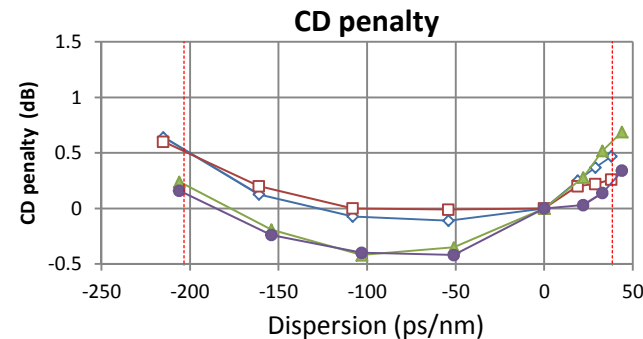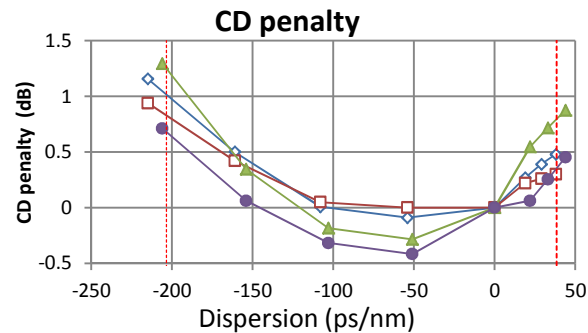
Beyond 10km :Stronger FEC

Several Potential hard decision FEC with 8-9dB NCG can help to achieve beyond 10km 400GbE
    RS-FEC, BCH-FEC, MLC-FEC or Staircase FEC. (wang_ecdc_01_0316)

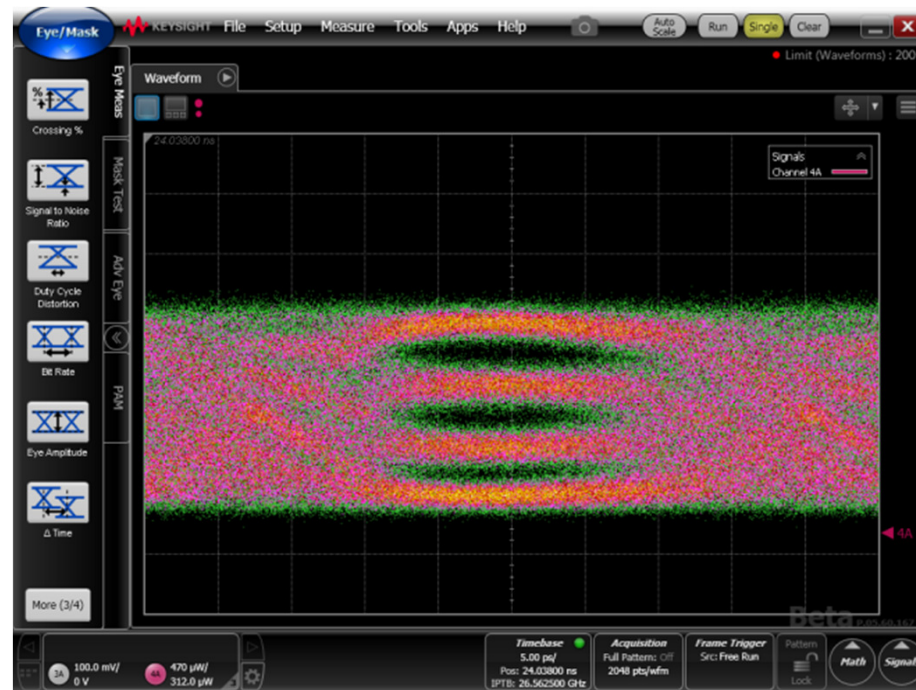NCG for HG FEC options, Assuming post BER@1E-13 objective.

Link budget example with High-power EML

ER=7.31dB

OMAouter=7.8dBm

PAM4 tx eye with high power EML

Conclusion

■56G PAM4 transmission with APD receiver
- Receivers sensitivity is about 18dB even assuming KP4-FEC limit. (about 10dB better than 400G FR8 specification.)
- Dispersion penalty is less than 1.5dB for 8-lambda LAN-WDM.
- There is still a room for stronger FEC overhead in terms of bitrate that supported in current components.
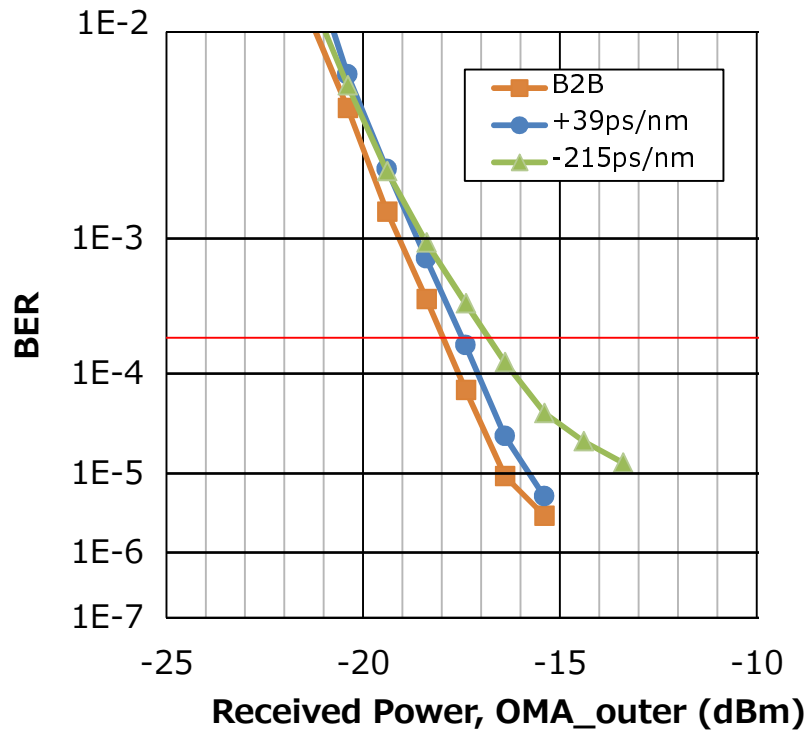 Stronger FEC improves Rx sensitivity and reduces dispersion penalty.

■Example performance with high power EML. (OMA outer 7.8dBm)

Backup slides

Measured BER at worst case dispersion
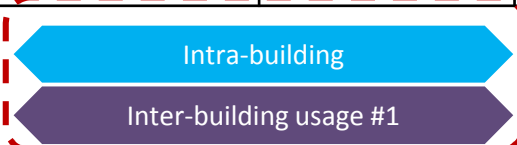
APD receiver sensitivity for 56Gb/s transmission
-16.8 dBm : worst case dispersion(negative)*
-18.0 dBm : back to back
-17.5 dBm : the worst case dispersion(Positive)*

* assumed 8-lane LAN-WDM over SMF
* assumed KP4 FEC limit as a reference
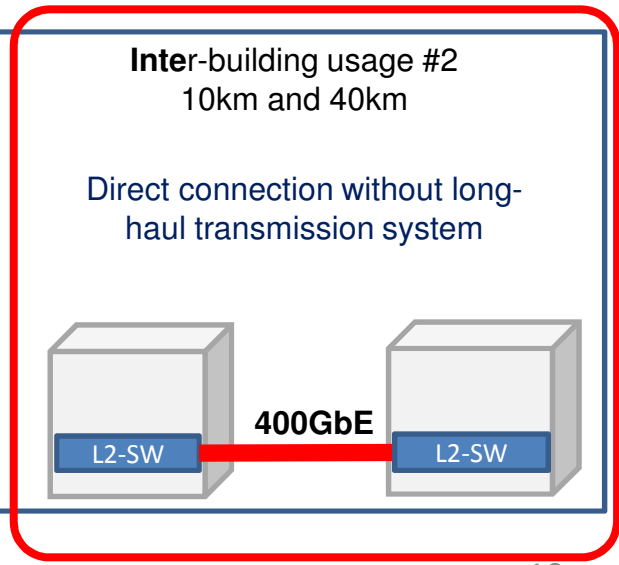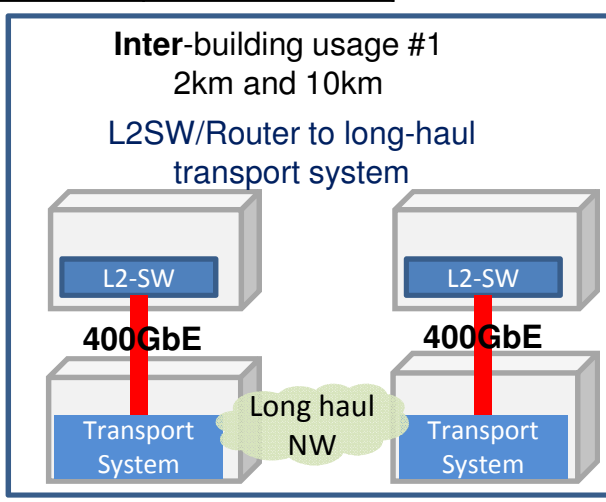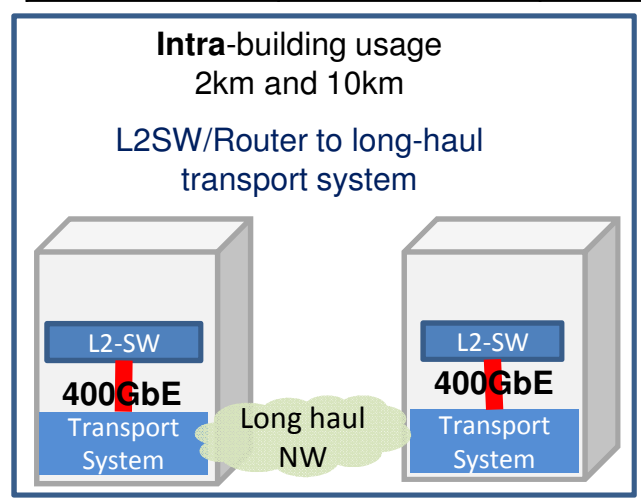
Without 8λWDM demux loss

400GbE 40km application

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

Media	Duplex single mode fiber		
Transmission distance	2km	10km	40km
Application	Intra-building / Inter-building usage #1	Intra-building / Inter-building usage #1 / Inter-building usage #2	Inter-building usage #2
802.3bs Objectives	✔	✔	-

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

・low-cost solution for some metro areas
・low-latency

Intra-building usage
2km and 10km

L2SW/Router to long-haul transport system

L2-SW
400GbE
Transport System — Long haul NW — Transport System
400GbE
L2-SW

Inter-building usage #1
2km and 10km

L2SW/Router to long-haul transport system

L2-SW
400GbE
Transport System — Long haul NW — Transport System
400GbE
L2-SW

Inter-building usage #2
10km and 40km

Direct connection without long-haul transmission system

L2-SW — **400GbE** — L2-SW

Worst-case dispersion for 40km SMF transmission

Worst-case dispersion for SMF transmission

■Negative dispersion

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

■Positive dispersion

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

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	1272.55 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