Further study of 400G with 4*100G PAM4

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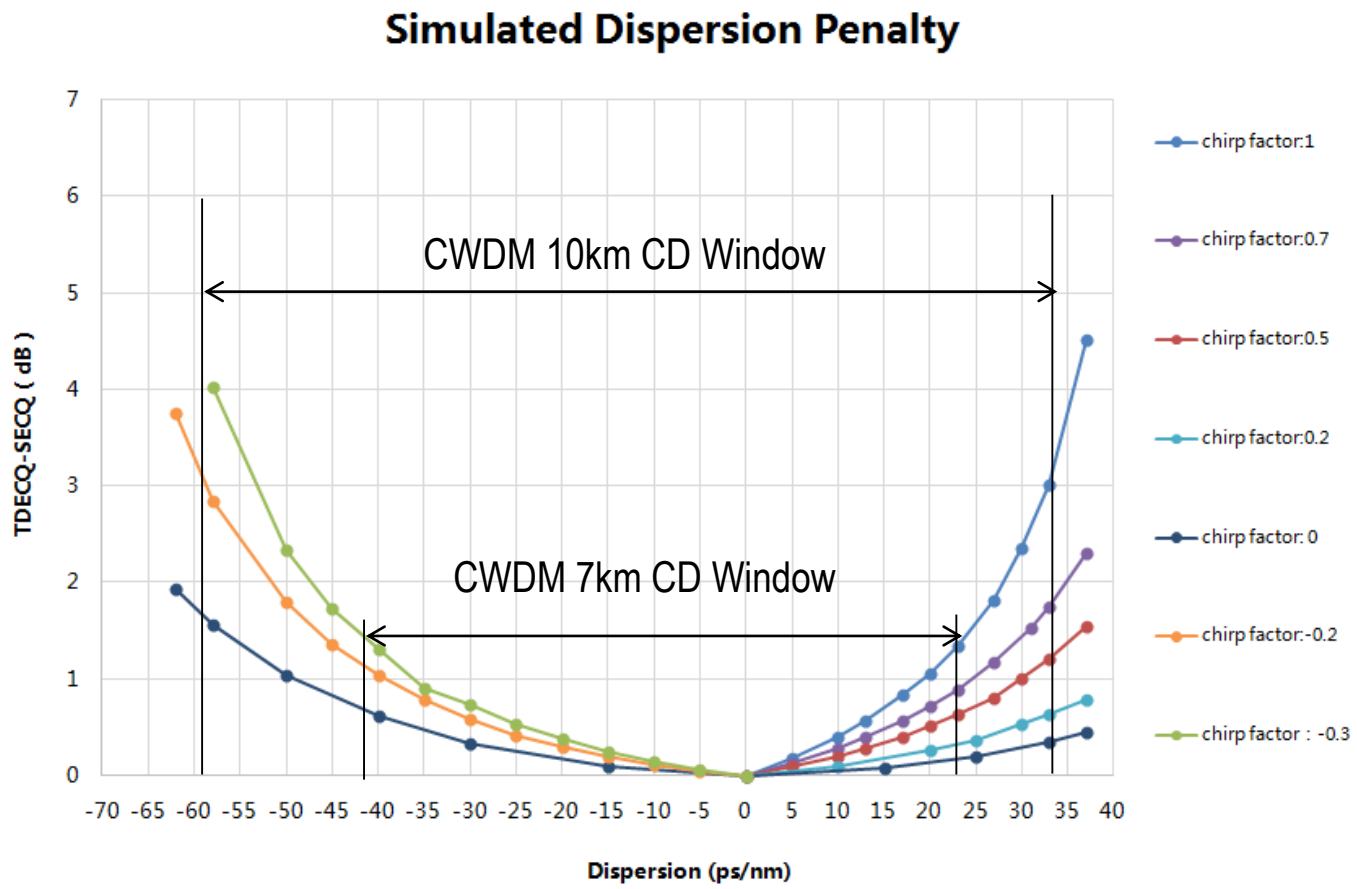
Introduction

- At last meeting, we showed our test result of 4*100G PAM4 TDECQ penalty based on CWDM wavelength grid. After that, we keep on study the relationship of EML chirp with TDECQ penalty.

- Furthermore, we studied the DGD penalty based on 4*100G 10km transmission.

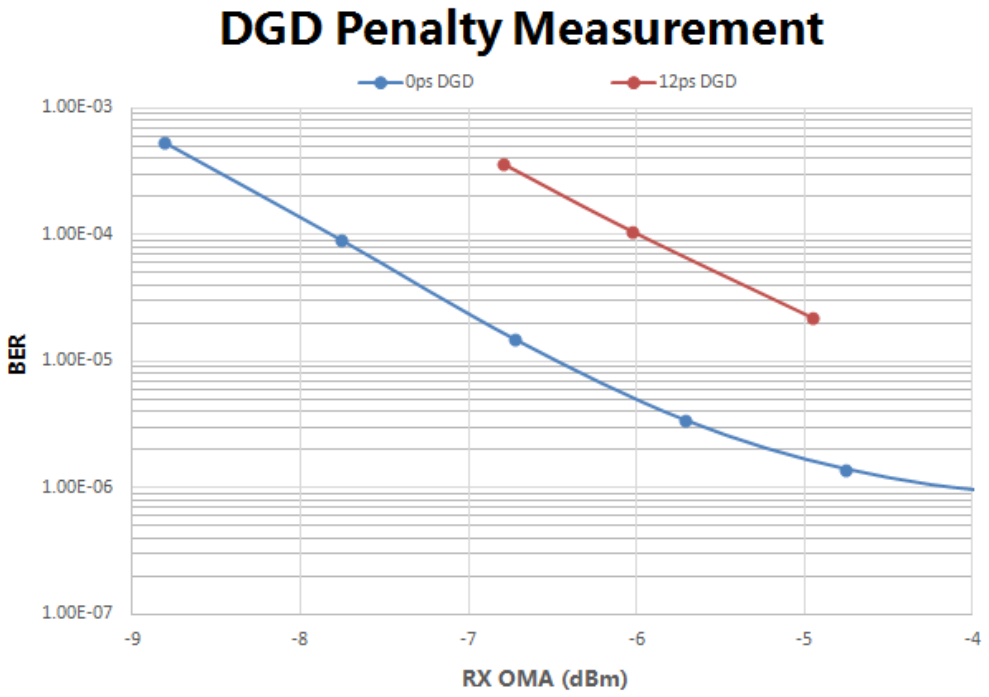
Chirp vs. TDECQ penalty

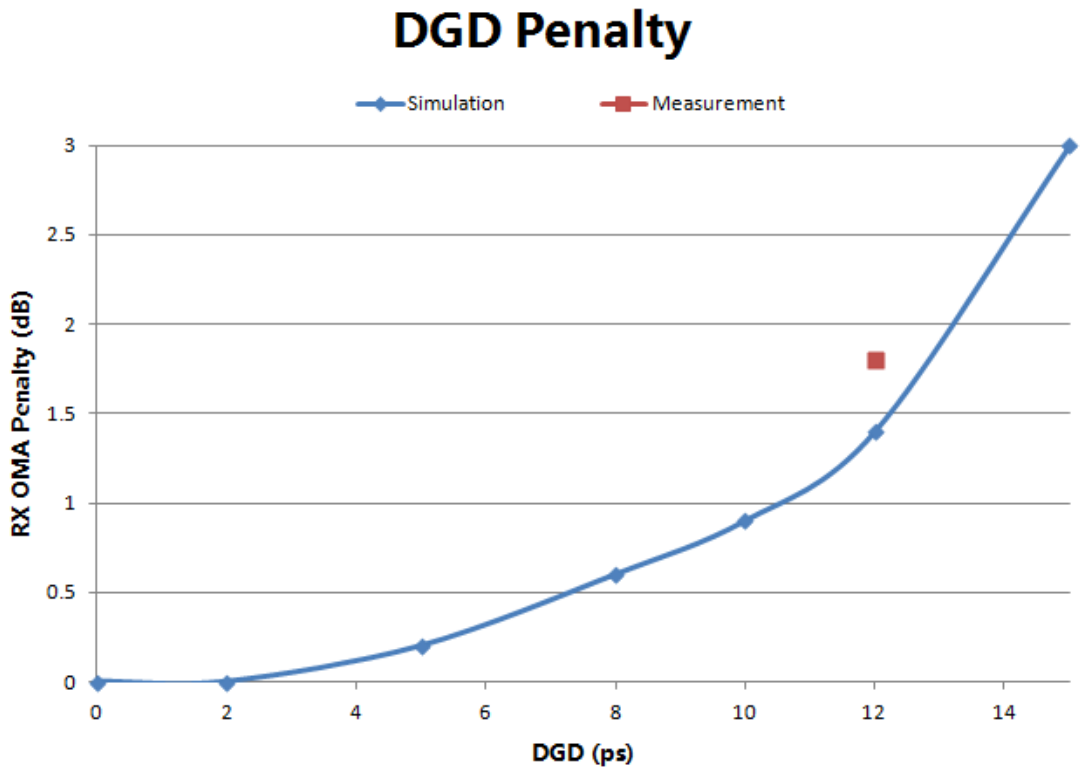
- During Jan's meeting, we were questioned about the chirp of the components we tested.
- For this question, we setup a simulation system to evaluate the relationship of chirp with TDECQ penalty. Chirp is critical for CD penalty but very difficult to control.
- The TDECQ penalty increased rapidly when CD window is expanded from 7km to 10km.



DGD Penalty

- The measured penalty at 12ps of DGD is similar to the simulation result, which is 1.8dB.
- The simulated RX OMA penalty is about 0.6dB due to 8ps of DGD.
- More details can be found at [shuai_cu_adhoc_050119.pdf]





Link budget study

- For a 10km transmission with CWDM wavelength grid, the following link budget need to be satisfied.

items	value	unit
transmission	10	km
fiber loss	6.3	dB
TDECQ	6*	dB
MPI	0.5	dB
DGD	0.6	dB
totally	13.4	dB

* 6dB is from assumption based on the average value of test result. Need further test and simulation for the final baseline.

- 13.4dB link budget is hard requirement for optical components. Therefore we need to find other way to balance the pressure, such as cooled EML, rebuilding the fiber, EML chirp control and so on.

Cost Study

	Un-cooled CWDM		Cooled CWDM		LAN-WDM	
Chirp control	Is it really feasible?	Need further study	possible	Need further study	no	Straight forward and robust
Chirp selection	Is it really feasible?	Need further study	possible	Need further study	no	Straight forward and robust
TEC	NA	-	yes	1.0?	yes	1.0?
New Fiber or Test the Fiber	possible	Need further study	no	-	no	-

- No matter what solution to be selected, the cost would be increased.
- To choose the right solution, cost is a key factor that needs to be carefully studied.

Extra thoughts

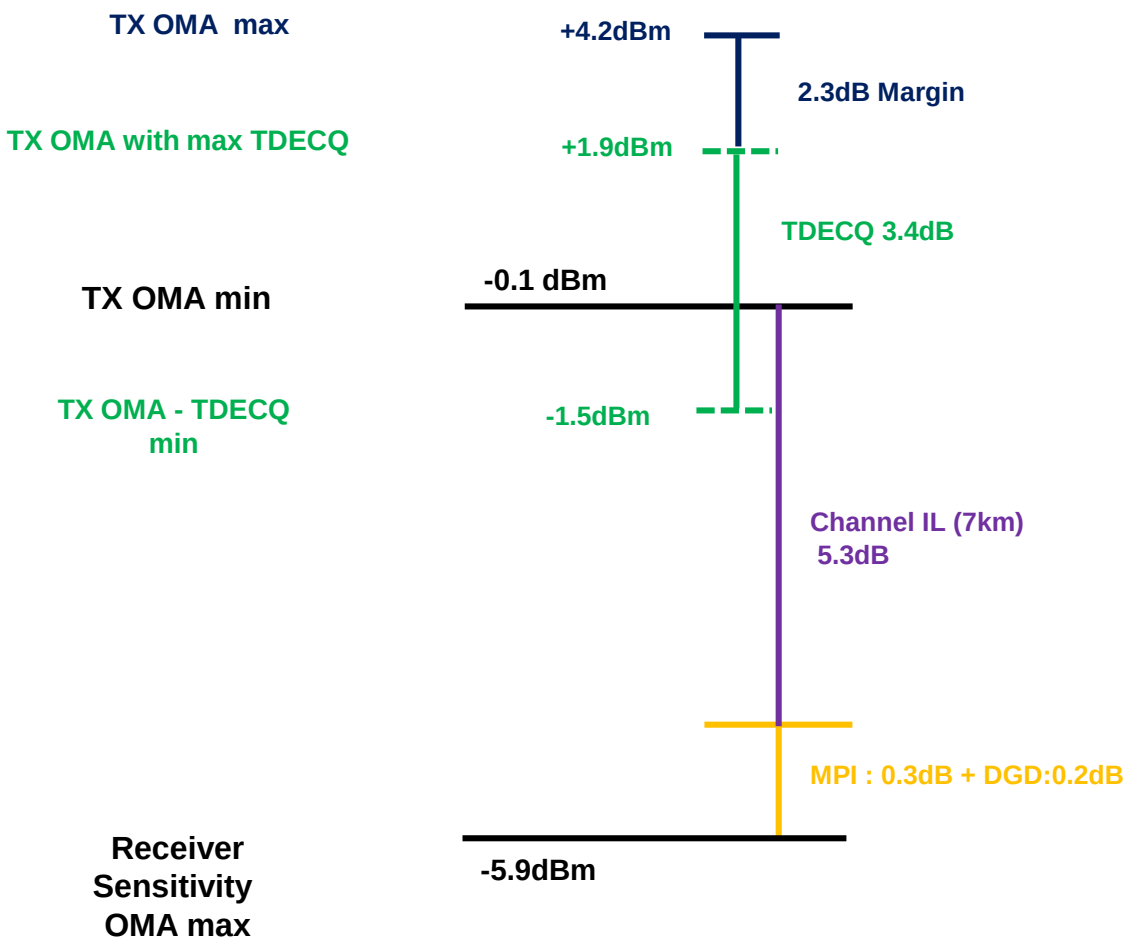
- How about a solution for a shorter reach to satisfy one part of market which could support an IEEE standard with a reasonable cost?

items	value	unit
transmission	7*	km
fiber loss	5.3	dB
TDECQ	3.4	dB
MPI	0.3	dB
DGD	0.2*	dB
totally	9.2	dB

* Numbers in this table need further study.

Extra thoughts - II

- For such application, the proposal of baseline could be:



Extra Thoughts - Transmitter Specifications

Description	Value	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1264.5 to 1277.5	nm
	1284.5 to 1297.5	
	1304.5 to 1317.5	
	1324.5 to 1337.5	
Side-mode suppression ratio (SMSR), (min)	30	dB
Total average launch power (max)	10	dBm
Average launch power, each lane (max)	4	dBm
Average launch power, each lane[a] (min)	-3.1	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane (max)	4.2	dBm
Outer Optical Modulation Amplitude (OMA_{outer}), each lane[b] (min)	-0.1	dBm
Difference in launch power between any two lanes (OMA_{outer}) max	4	dB
Launch power in OMA_{outer} minus TDECQ, each lane (min): for extinction ratio ≥ 4.5 dB for extinction ratio ≥ 4.5 dB	 -1.5 -1.4	dBm
Transmitter and dispersion penalty eye closure for PAM4 (TDECQ), each lane (max)	3.4	dB
TDECQ – 10*$\log_{10}(C_{eq})$, each lane (max)[d]	3.4	dB
Average launch power of OFF transmitter, each lane (max)	-20	dBm
Extinction ratio (min)	3.5	dB
Transmitter transition time (max)	17	ps
$RIN_{15.6}$ OMA (max)	-136	dB/Hz
Optical return loss tolerance (max)	15.6	dB
Transmitter reflectance[c] (max)	-26	dB

Extra Thoughts - Receiver Specifications

Description	Value	Unit
PAM4 Signaling rate, each lane (range)	53.125 ± 100 ppm	GBd
Lane wavelengths (range)	1264.5 to 1277.5	nm
	1284.5 to 1297.5	
	1304.5 to 1317.5	
	1324.5 to 1337.5	
Damage threshold, each lane (min)[a]	5.0	dBm
Average receive power, each lane (max)	4.0	dBm
Average receive power, each lane [b] (min)	-8.4	dBm
Receive power, each lane (OMA_{outer}) (max)	4.2	dBm
Difference in receive power between any two lanes (OMA_{outer}) (max)	4.1	dB
Receiver reflectance (max)	-26	dB
Receiver sensitivity (OMA_{outer}), each lane [c] (max)	RS =MAX(-5.9,SECQ-7.3)	
Stressed receiver sensitivity (OMA_{outer}), each lane [d] (max)	-3.9	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ), lane under test	3.4	dB
SECQ – $10*\log_{10}(C_{eq})$, lane under test (max) [e]	3.4	dB
OMA_{outer} of each aggressor lane	0.2	dBm

Extra Thoughts - Power Budget

Description	Value	Unit
Power budget (for max TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 9.2 9.3	dB
Operating distance	7	km
Channel insertion loss[a]	5.3	dB
Maximum discrete reflectance	See Table Below	dB
Allocation for penalties[b] (for max TDECQ) for extinction ratio ≥ 4.5 dB for extinction ratio < 4.5 dB	 3.9 4.0	dB
Additional insertion loss allowed	0	dB

[a] The channel insertion loss is calculated using the maximum distance specified in Table 2-2 and cabled optical fiber attenuation of 0.47 dB/km plus an allocation for connection and splice loss given in 5.2.1.
[b] Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Number of discrete reflectance above -55dB	Maximum value for each discrete reflectance	Unit
1	-22	dB
2	-29	dB
4	-33	dB
6	-35	dB
8	-37	dB
10	-39	dB


рахмат
danke
謝謝
ngiyabonga
teşekkür ederim
Баярлалаа
mersi
barka
welalin
tack
спасибо
faafetai lava
vinaka
blagodaram
dank je
misaotra
matondo
paldies
mahalo
kiitos
dankie
thank you
gracias
tapadh leat
хвала
asante
manana
bedankt
nandri
hvala
mauruuru
köszönöm
enkosi
djiere dieuf
mochchakkeram
dziękuję
chnorakaloutioun
gracies
sulpay
go raibh maith agat
taiku
dekuji
sukriya
kop khun krap
obrigado
mesi
sagolun
arigatō
takk
dakujem
trugarez
ありがとう
grazie
najis tuke
terima kasih
tanemirt
rahmet
diolch
dhanyavadagalu
shukriya
мерси
kam sah hamnida
감사합니다
xiexie
ευχαριστώ
merci