The necessity of enhanced FEC for low cost 25G PON

Dekun Liu

2017 Sep.

www.huawei.com

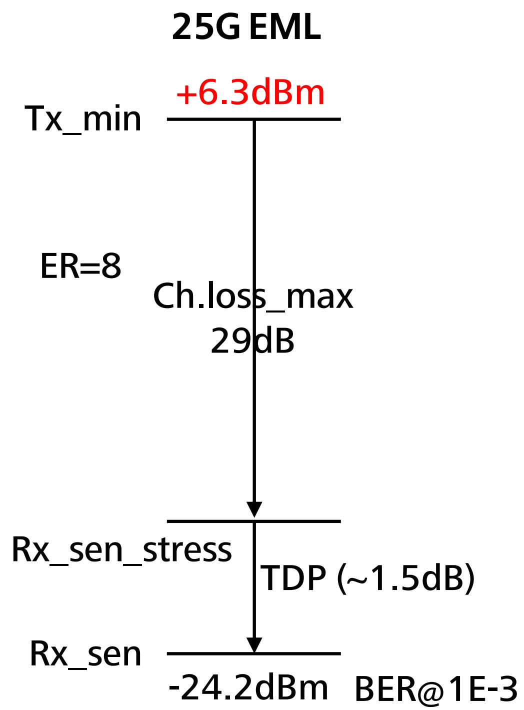
HUAWEI TECHNOLOGIES CO., LTD.

HUAWEI

Background

- The power budget of 25G and 100G have been analyzed by many contributions in previous meetings, but some gap are still there to meet power budget requirement .
- Several FECs also have been analyzed in the past three meetings, but there is still no decision which we should use.
- In this contribution, we analyze the power budget gap and discuss the necessity of enhanced FEC.

Power budget gap for 25G downstream



25G EML launch power

harstead_3ca_1a_0716

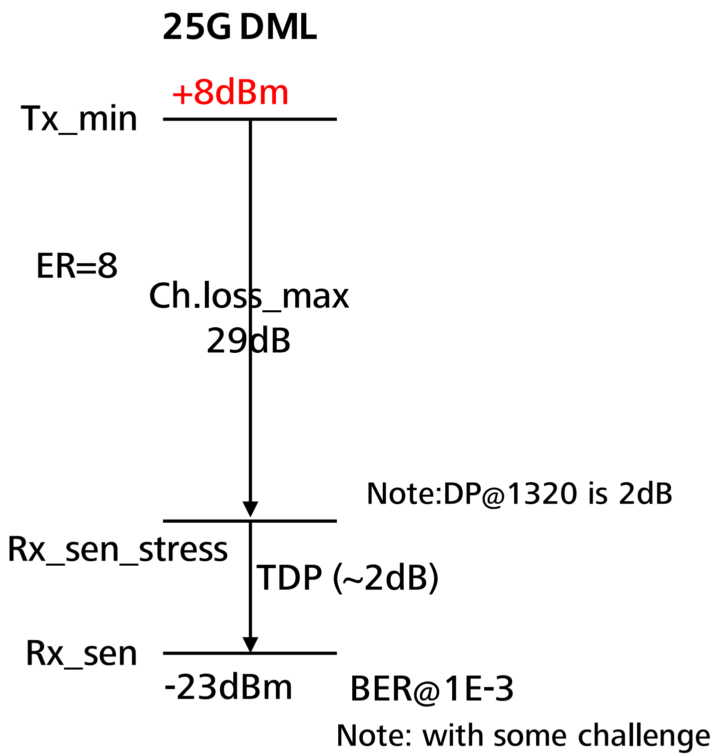
AVPmin (dBm)	number	mean	σ
EML	6	4.5	0.8
cooled DML	8	7.0	1.2
uncooled DML	6	4.7	1.5

liu_3ca_4_0517.pdf

	25G EML		25G cooled DML		25G uncooled DML		25G EML+SOA	
	Power (dBm)	ER (dB)	Power (dBm)	ER (dB)	Power (dBm)	ER (dB)	Power (dBm)	ER (dB)
vendor 1	3~4	8	7	4.5	5~6	4.5	7 (note 1)	8
vendor 2	3	8	5	5	4	4	7	8
vendor 3	4	6	4	4	xx	xx	6~7	6
vendor 4	2.5	8	5.8	4	xx	xx	xx	xx
vendor 5	4.3	8	5.5	4.5	4	4	7	7
vendor 6	4.5	8	6	5	4	4	x	x

- 6.3dBm is very challenging for 25G EML without amplifier
- Based on the previous survey from vendors, 4~4.5dBm Tx power seems the right one for 25G EML without much challenge.

Power budget gap for 25G upstream



25G EML launch power

harstead_3ca_1a_0716

AVPmin (dBm)	number	mean	σ
EML	6	4.5	0.8
cooled DML	8	7.0	1.2
uncooled DML	6	4.7	1.5

liu_3ca_4_0517.pdf

	25G EML		25G cooled DML		25G uncooled DML		25G EML+SOA	
	Power (dBm)	ER (dB)	Power (dBm)	ER (dB)	Power (dBm)	ER (dB)	Power (dBm)	ER (dB)
vendor 1	3~4	8	7	4.5	5~6	4.5	7 (note 1)	8
vendor 2	3	8	5	5	4	4	7	8
vendor 3	4	6	4	4	xx	xx	6~7	6
vendor 4	2.5	8	5.8	4	xx	xx	xx	xx
vendor 5	4.3	8	5.5	4.5	4	4	7	7
vendor 6	4.5	8	6	5	4	4	x	x

- A big gap for upstream power budget!

Power budget improvement measurements

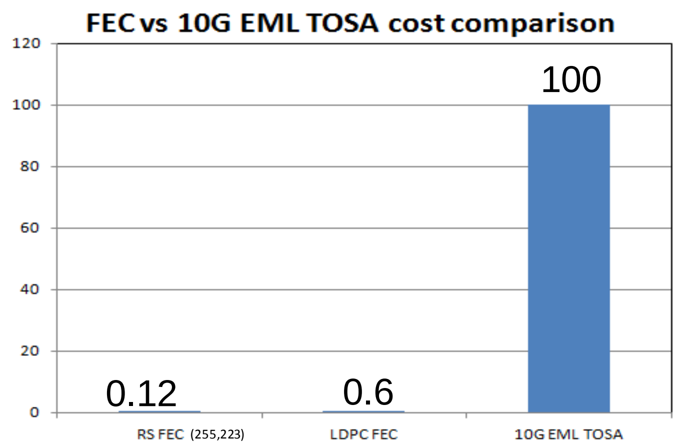
- Increase the launch power
  - Such as integrate an amplifier, improve the coupling efficiency, improve the chips efficiency
  - Increase the cost very quickly

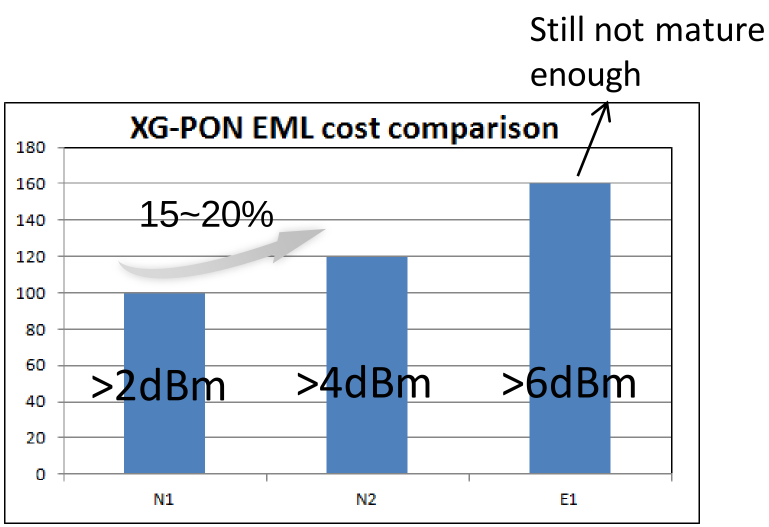
- Enhanced FEC to improve sensitivity
  - LDPC, BCH,

- Add a pre-amplifier to improve the sensitivity
  - Pre-amplifier is very cost, which only could be economic in OLT
  - Result in high power consumption, low ports density
  - Gain limited by SNR, dynamic range, multiple channel crosstalk…

FEC vs High Tx power Cost analysis

- The cost of FEC is much smaller compared with 10G EML
  - Every RS FEC only occupy <0.1mm^2 area in 10G EPON OLT MAC chip with 16nm node step, very small part of the total chip cost
  - The cost trend of ASIC chips complies with Moore's law
- The cost of optical transmitter strongly depends on the required launch power
  - High launch power requirement results in lower yield, higher coupling efficiency , higher power consumption requirement
  - Every class(2dB more) takes roundabout 15~20% extra cost based on 10G PON
- **Using enhanced FEC is much more economic compared with increasing the launch power**





HUAWEI

Tx Launch power in other IEEE standards

25 Gb/s Ethernet (IEEE 802.3cc)

PMD	Link Distance	Fiber Count and Media Type	Technology
25GBASE-LR	10 km SMF	2-f SMF	1x25G NRZ
25GBASE-ER	40 km SMF	2-f SMF	1x25G NRZ

Publication expected in 2017

Transmit Characteristics

Description	25GbE-LR	25GbE-ER	Unit
Signaling rate (range)	25.78125 ± 100ppm		GBd
Operating BER (max)	$5x10^{-5}$		
Wavelength (range)	1295 to 1325	1295 to 1310	nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Average launch power (max)	2.5	6.0	dBm
Average launch power (min)	-6.5	2.0	dBm
Optical Modulation Amplitude (OMA), (max)	3.0	6.0	dBm
Optical Modulation Amplitude (OMA), (min)	-4	1.4	dBm
Launch power in OMA minus TDP (min)	-5	0.4	dBm
Transmitter and dispersion penalty (TDP), (max)	2.7	2.7	dB
Average launch power of OFF transmitter (max)	-30		dBm
Extinction ratio (min)	3.5	4	dB
$RIN_{20}OMA$ (max)	-130		dB/Hz
Optical return loss tolerance (max)	20		dB
Transmitter reflectance (max)	-12		dB
Transmitter eye mask definition (X1, X2, X3, Y1, Y2, Y3)	{0.31, 0.4, 0.45, 0.34, 0.38, 0.4}		

100Gb/s Ethernet

Table 88–6—100GBASE-LR4 and 100GBASE-ER4 operating ranges

PMD type	Required operating range
100GBASE-LR4	2 m to 10 km
100GBASE-ER4	2 m to 30 km
	2 m to 40 km[a]

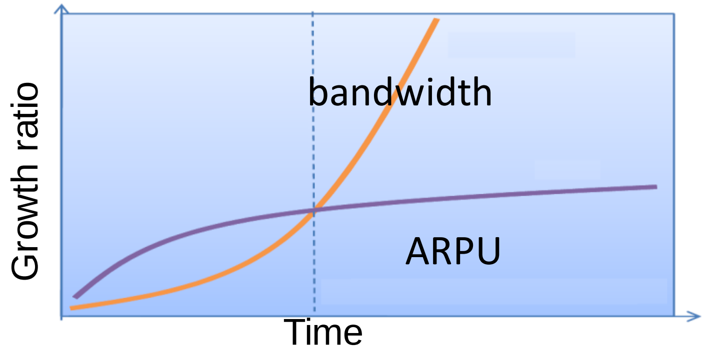
Table 88–7—100GBASE-LR4 and 100GBASE-ER4 transmit characteristics

Description	100GBASE-LR4	100GBASE-ER4	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm		GBd
Lane wavelengths (range)	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19		nm
Side-mode suppression ratio (SMSR), (min)	30		dB
Total average launch power (max)	10.5	8.9	dBm
Average launch power, each lane (max)	4.5	2.9	dBm
Average launch power, each lane[a] (min)	−4.3	−2.9	dBm

- The launch power of existing optics in datacenter are much lower than the target value of 25G PON.

Low cost is very important for 25G !!!

- The bandwidth in the network increases much faster than operators' revenue does
  - New generation PON must be more cost effective per Gbit than the previous generation PON
- The capacity of 25G PON is quite close to 10G PON (~2 times net capacity)
  - The delta cost compared with 10G PON must be very small (such as 20% more ?)
- 10G PON has a lot of merits than 25G PON on cost, but it's still too expensive to replace GPON deployment in near term
  - Very mature technology
  - Wide industry chain
  - Medium launch power and sensitivity requirement
- 25G must do even better on cost to be success!



Globle PON ports price and revenue forecast

- Enhanced FEC can lower down the cost of optics with negligible delta cost!
- So we should try to go to the FEC limitation first !

FEC's gain ability

effenberger_3ca_1_1116

Enhanced FEC example for 2dB coding gain improvement				
FEC code	Decision	Length(bit)	Code rate	Electrical coding gain(dBe) @e-12
RS(2047,1431)	Hard	10230	0.70	9.6
BCH(4095,3081)	Hard	4095	0.75	9.6
BCH(186,161) X BCH(209,184)	Hard	38874	0.76	10.5
LDPC(19200,16000)	Hard	19200	0.83	9.6

laubach_3ca_1_0517.pdf

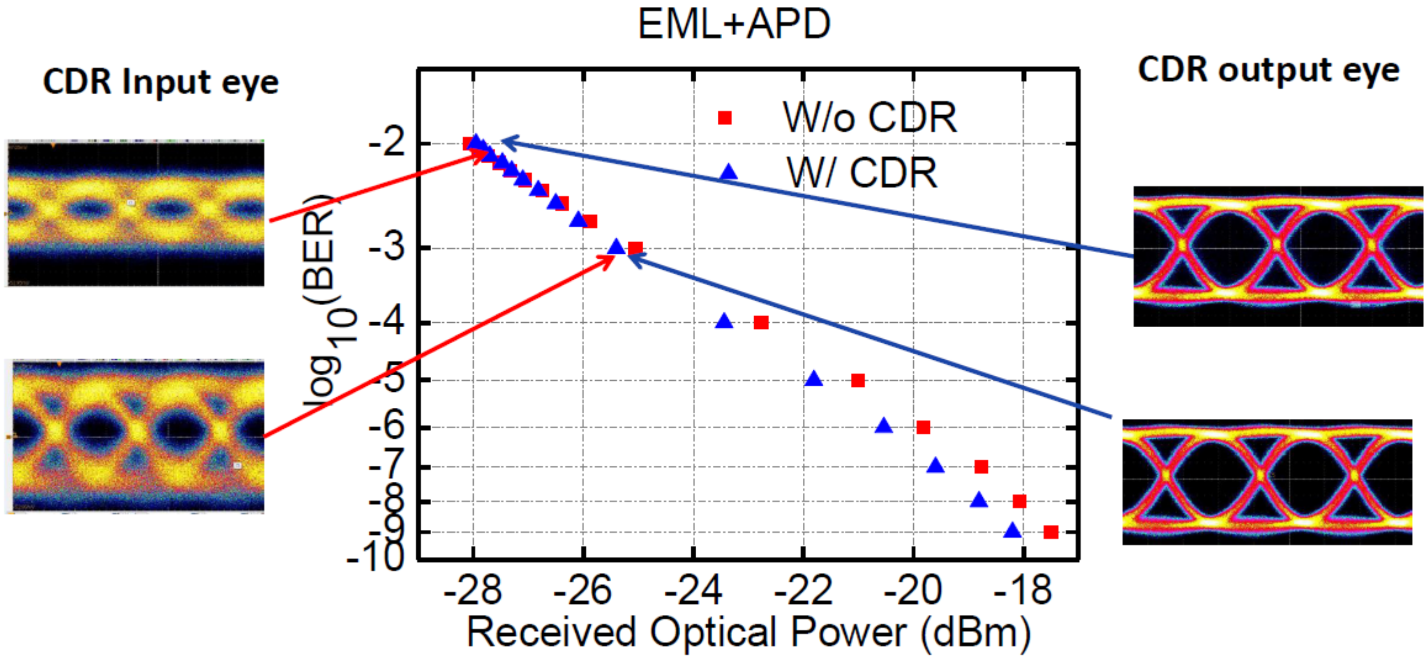
	Length	Rate	Parity	User	Encoded	NECG[1] (dB)		Notes
						AWGN	Gilbert Burst	
Folded BCH	2kB	0.83	3272	16576	19848	2.25	1.48	bits
	4kB	0.83	6064	30784	36848	2.6	1.78	bits
LDPC	2kB	0.848	2816	15677	18493	2.46	1.8	bits (18493,15677)
	2kB	0.833	3200	16000	19200	2.82	2.12	bits (19200,16000)

There are several types FECs which can provide at least 1.5dB extra optical gain over RS(255,223)

CDR recover @1E-2 BER

Test Results: Scenario 1

jinyinrong_3ca_1_0717.pdf

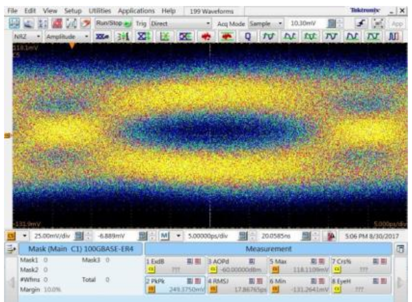


- ✓ The RX performance with and without CDR is almost the same.
- ✓ It shows the eye remains open and clear after 25G CDR at the BER of 1E-2.
- ✓ It demonstrates that the 25G CDR is still in the Lock state at the BER of 1E-2.

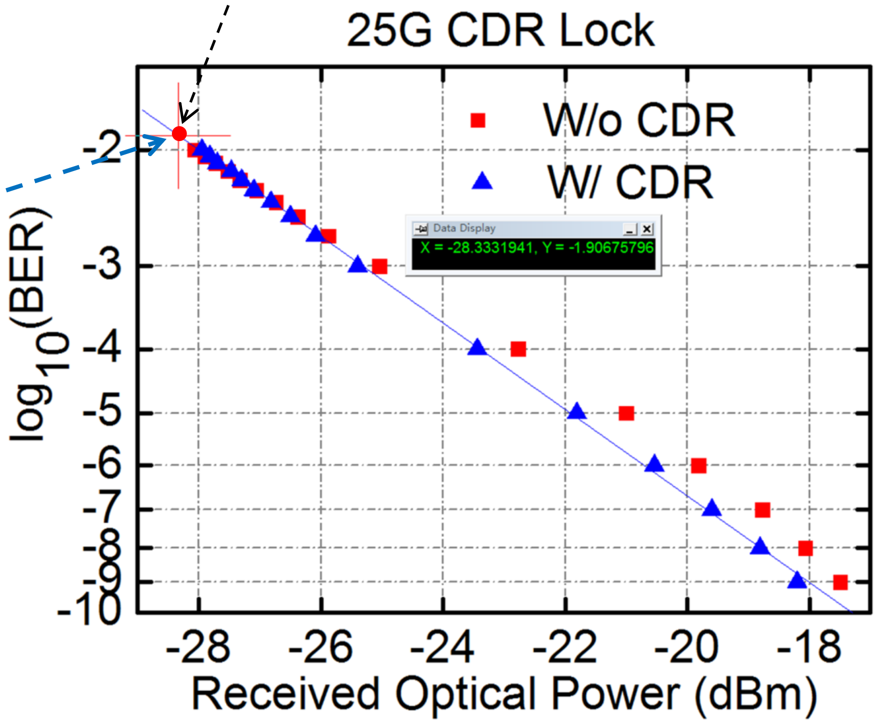
25G CDR still can be in the lock state at BER 1E-2

CDR margin beyond BER 1E-2

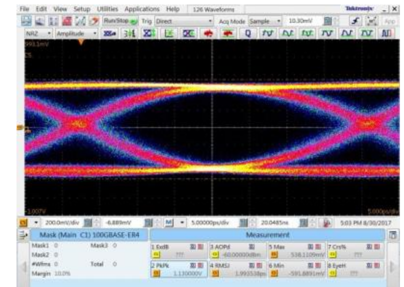
CDR input eye diagram at the break point



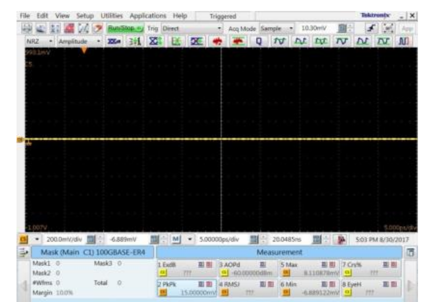
Break point



CDR output eye diagram before the break point



CDR output eye diagram after the break point



There are extra 0.4dB margin for 25G CDR beyond 1E-2, the break point is 1.24E-2 ($10^{-1.907}$)

Final thoughts

- Based on above analysis, the power budget of 25G and 100G PON is very challenging, it requires 25G transmitters with very high launch power to meet the power budget requirement.

- The cost of optical transmitter will increase distinctly when the required launch power is increased, while the delta cost of enhanced FEC is much smaller compared with the cost of optics

- Several FECs can provide >1.5dB extra opticall gain and the CDR can still work at BER 1E-2.

- 25G and 100G PON should utilize enhanced FEC to lower down the requirement on optics as possible

Straw Poll

- In order to lower down the cost of optics, do you agree 802.3ca should specify a FEC with at least 1.5dB extra optical gain compared with RS(255,223)?

  Yes:

  No:

  Abstain:

Thank you

www.huawei.com