Security Level:

100G EPON Power Budget Analysis

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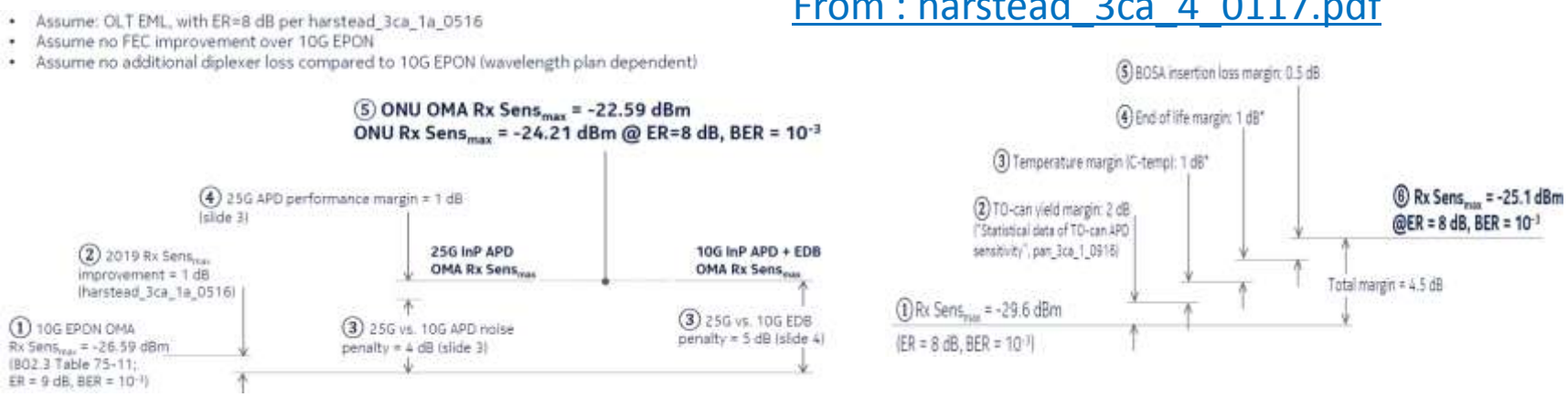
Background

- Last meeting in Huntington , it was agreed that -24.2dBm at BER =1E-3 and ER=8dB is adopted as the starting point for 25G ONU receiver sensitivity .
- This contribution further analyzes the power budget of 100G EPON based on this starting point.

25G APD capability

From : harstead_3ca_4_0117.pdf



- The -24.2dBm@1E-3 at ER=8dB based on EML transmitter is a good reflection on the 25G InP APD sensitivity capability at the BOSA input point.
- Ge/Si APD may have some further improvement space, but it depends on the industry chain availability.
- The sensitivity based on DML transmitter will be different.

DML vs EML OMA sensitivity difference

source	EML OMA sensitivity (dBm@1E-3)	DML OMA sensitivity (dBm@1E-3)	Difference (dB)	Ref
Finisar	-23.13	-22.47	0.66	cole_3ca_1_0316 (based on 28Gb/s)
sumitomo APD A	-23.95	-23.11	0.84	tanaka_3ca_1_1116
sumitomo APD B	-24.91	-24.09	0.82	tanaka_3ca_1_1116
Huawei	-24.54	-23.25	1.29	liu_3ca_1_0117 liudekun_3ca_1_0317
Note: the OMA values are calculated by the author based on the sensitivity and ER from the reference				

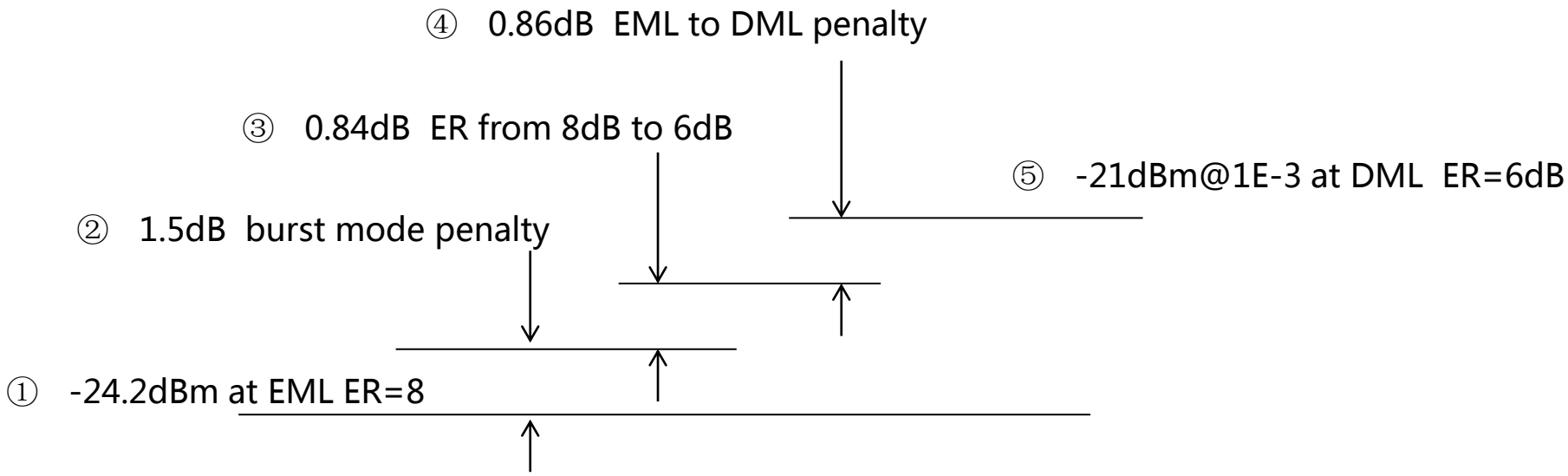
- Generally speaking, due to the poorer eye diagram quality , DML transmitter will have poorer sensitivity by ~1dB than EML transmitter even at the same extinction ratio.

25G APD sensitivity based on DML

Contributor	Sensitivity (dBm@1E-3)	ER(dB)	Sensitivity(dBm) with 6dB ER	wavelegnth (nm)	Ref
Finisar	-22.8 (at 28Gb/s)	5.24	-23.25	1308.8	cole_3ca_1_0316
Sumitomo (A)	-23.49	5.3	-23.89	1309.3	tanaka_3ca_1_1116
Huawei	-23.79	5.6	-24.03	1295.3	liudekun_3ca_1_0317

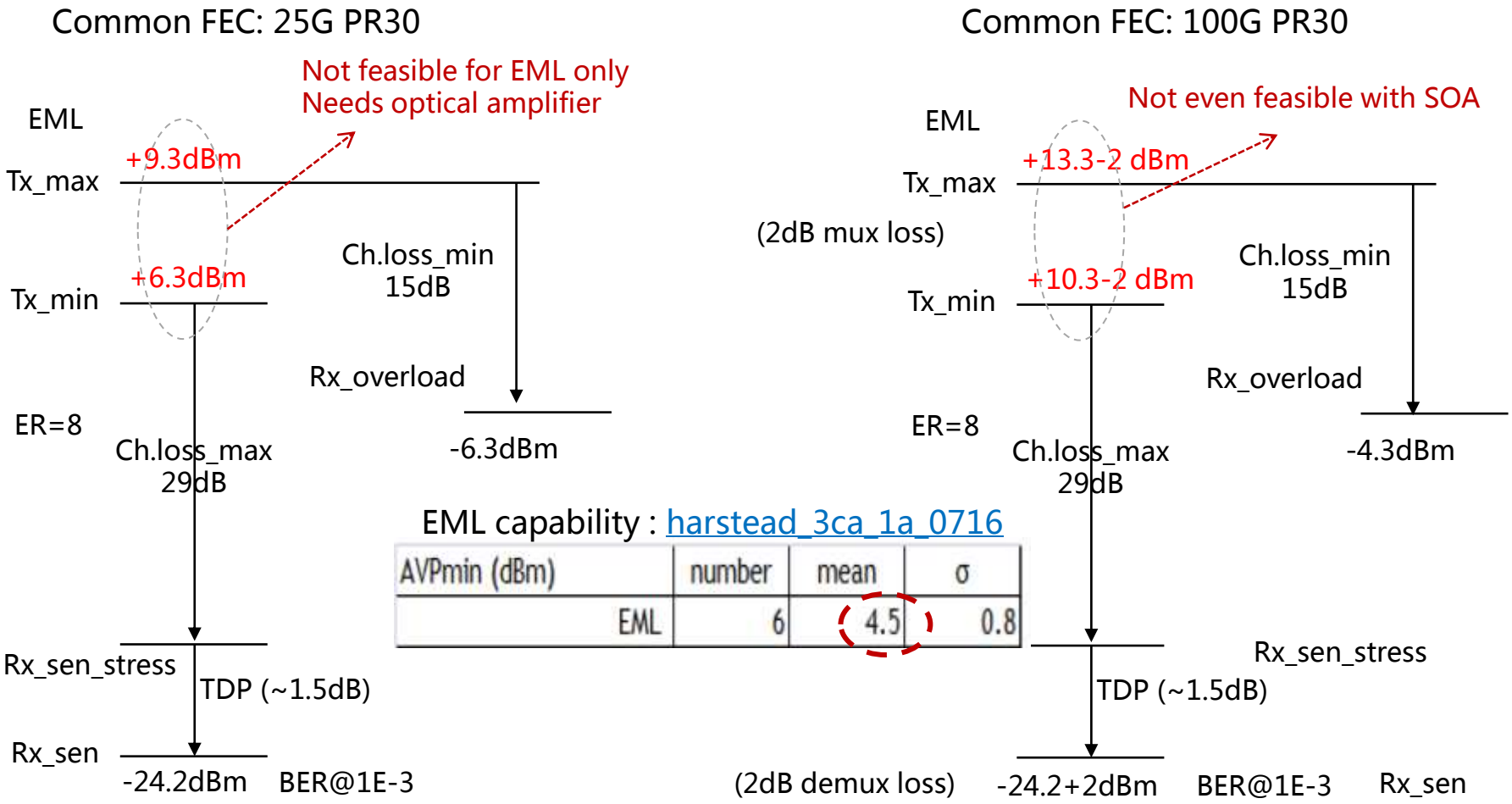
- All these sensitivities , generally speaking , are measured based on continuous mode at room temperature in the lab.
- -24dBm@1E-3 at 6dB ER based on DML seems the most typical value in the lab at continuous mode.
- Same with downstream, if we consider 1dB full temperature margin, 1.5dB burst mode penalty , 0.5dB margin for end of life, **-21dBm@1E-3 seems the right capability in the OLT side.**

Iteration from the downstream



- If we take the -24.2dBm@1E-3 at EML ER=8 as the starting point, leave 1.5dB burst mode penalty, 0.84dB penalty for ER from 8dB to 6dB and 0.86dB EML to DML penalty, we can get the same number -21dBm@1E-3 sensitivity.

Downstream power levels analysis(1)



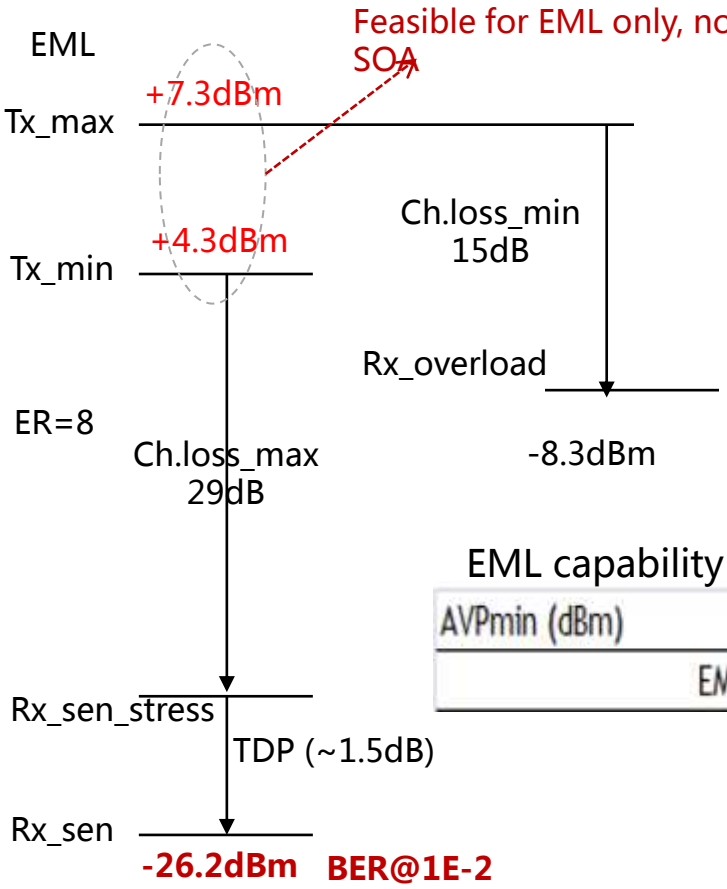
EML capability : harstead_3ca_1a_0716

AVPmin (dBm)	number	mean	σ
EML	6	4.5	0.8

If use common FEC (BER@1E-3), 25G OLT will need boost amplifier to enhance the launch power, while 100G OLT may not meet the power budget even with SOA as boost amplifier.

Downstream power levels analysis(2)

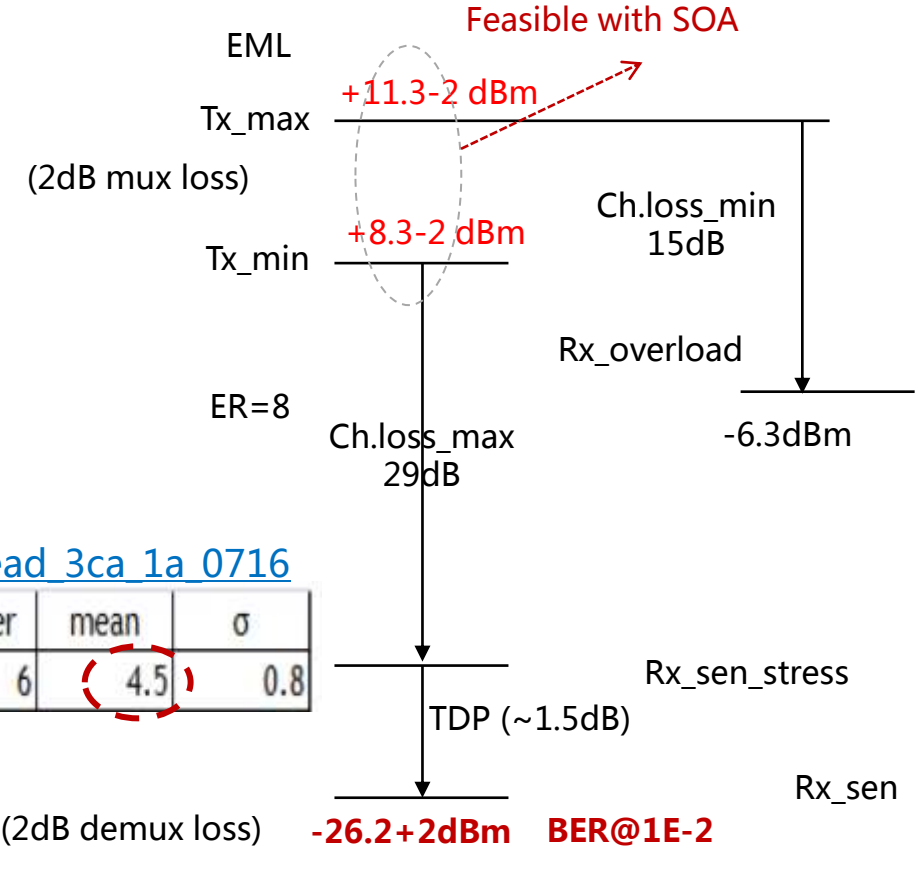
Enhanced FEC: 25G PR30



EML capability : harstead_3ca_1a_0716

AVPmin (dBm)	number	mean	σ
EML	6	4.5	0.8

Enhanced FEC: 100G PR30



- If use enhanced FEC (BER@1E-2), 25G OLT won’ t need boost amplifier any more , which will benefit the cost, power consumption and ports density by a noticeable ratio .
- 100G OLT is still feasible when SOA is used as boost amplifier.

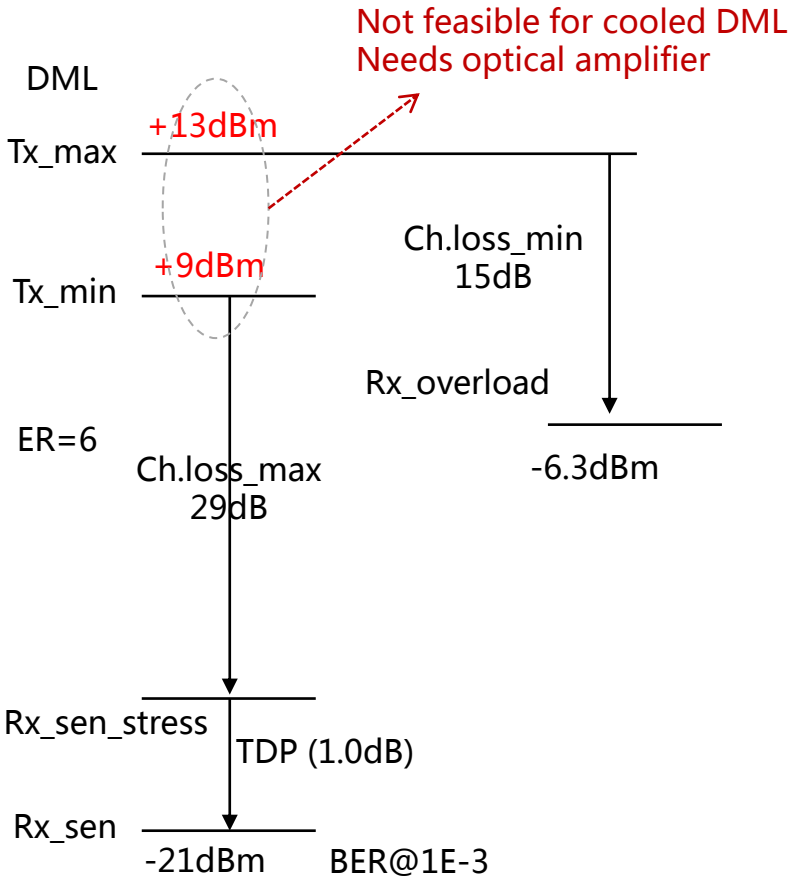
Upstream power levels analysis

- Assumption:
  - 25G DML laser as the ONU transmitter
  - ER = 6 dB*
  - No amplifier in ONU Tx (for low cost)
  - TDP = 1.0 in upstream* (Considering the low dispersion penalty for upstream in O-band)
  - -21dBm@1E-3 as the starting point for upstream

* ER = 6dB and 1.0dB TDP are assumed only for initial analysis

Upstream power levels analysis

Common FEC: 25G PR30



DML capability : 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
ER (dB)			
EML	6	7.5	0.8
cooled DML	8	5.3	0.9
uncooled DML	6	4.7	1.0

- 9dBm is far beyond the uncooled DML capability and will result in high cost of ONU.
- Preamplifier and enhanced FEC may be need to meet the 29dB power budgets.
- 100G upstream will be even more challenging , it needs further study.

Enhanced FEC example for 1dB coding gain improvement				
FEC code	Decision	Length(bit)	Code rate	Electrical coding gain(dBe) @e-12
RS(1023,847)	Hard	10230	0.83	8.5
BCH(4095,3501)	Hard	4095	0.85	8.5
LDPC(16000,13952)	Hard	16000	0.87	8.9
LDPC(8000,6848)	Hard	8000	0.86	8.8

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

effenberger_3ca_1_1116

Enhanced FEC implementation

FEC Code	Length (bits)	Code Rate	Electrical Coding gain(dBe) @E-12
RS(2047,1431)	10230	0.7	9.6
BCH(4095, 3081)	4095	0.75	9.6
BCH(186,161) X BCH(209,184)	38874	0.76	10.5
Folded Product Code	16384	0.8	10.1
RS(1023,847)	10230	0.83	8.5
LDPC(19200,16000)	19200	0.83	9.6
Folded Product Code	36864	0.83	9.9
Folded Product Code	16384	0.83	9.7
BCH(4095, 3501)	4095	0.85	8.5
Folded Product Code	36864	0.85	9.7
Folded Product Code	16384	0.85	9.4
LDPC(8000,6848)	8000	0.86	8.8
LDPC(16000,13952)	16000	0.87	8.9
Folded Product Code	36864	0.87	9.4
Folded Product Code	16384	0.87	9.2
Folded Product Code	36864	0.9	9
Folded Product Code	16384	0.9	8.6

laubach_3ca_1_0117

Summary :

- The downstream and upstream of 25G and 100G EPON power levels have been analyzed.
- For downstream, if we re-use the 1E-3 RS FEC , optical amplifier will need to be used to boost the launch power. For 100G, the downstream launch power is even challenging with boost amplifier.
- For upstream, there is still a big gap between DML laser capability and the required power budget requirement.
- A preamplifier in OLT or enhanced FEC will help to meet the upstream power budget and lower down the cost of ONU.

Thank you

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