A comment on Table 88-7 and 88-8 in Draft 1.0

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Introduction

➢ One of the solutions to reduce the cost of 100GBASE-LR4 is leveraging DML. But some of the parameters in the optical spec (Table. 88-7, 88-8) would be better to be tweaked for DML use.

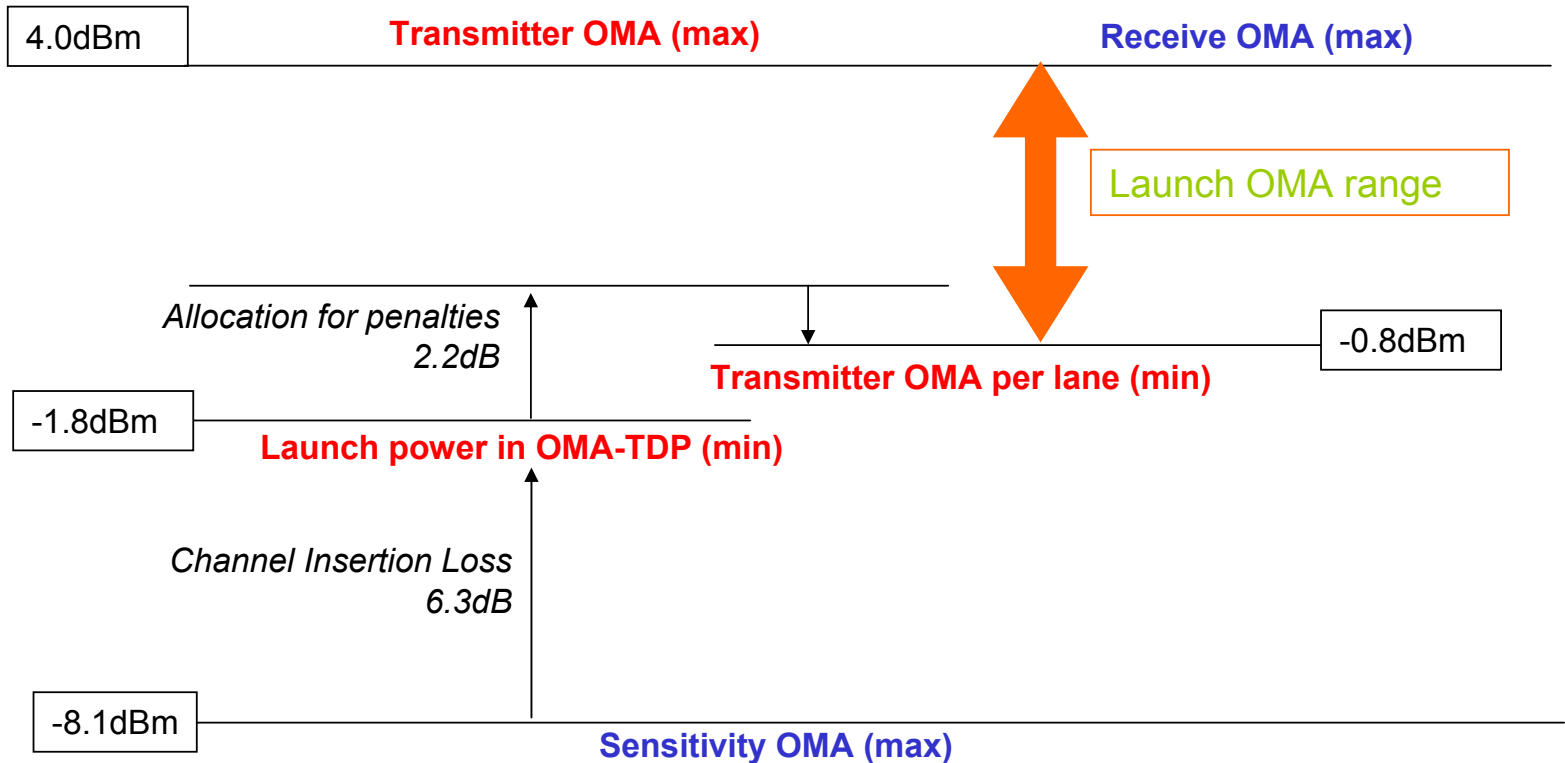➢ This material shows what the issues are and proposes the remedy of this issue.

Optical specs in 100GBASE-LR4

Description	100GBASE–LR4	Unit
Signaling speed per 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)	10.0	dBm
Average launch power per lane (max)	4.0	dBm
Average launch power per lane[a] (min)	−3.8	dBm
Optical Modulation Amplitude (OMA), each lane (max)	4.0	dBm
Launch power per lane (min) in OMA minus TDP[b]	−1.8	dBm
Optical Modulation Amplitude (OMA), each lane (min)	−0.8	dBm
Transmitter and dispersion penalty, each lane (max)	2.2 (See editors note)	dB
Average launch power of OFF transmitter, each lane (max)	−30	dBm
Extinction ratio (min)	4.0	dB
$RIN_{12}OMA$ (max)	−132	dB/Hz
Optical return loss tolerance (max)	12	dB
Transmitter reflectance[c] (max)	−12	dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	TBD	

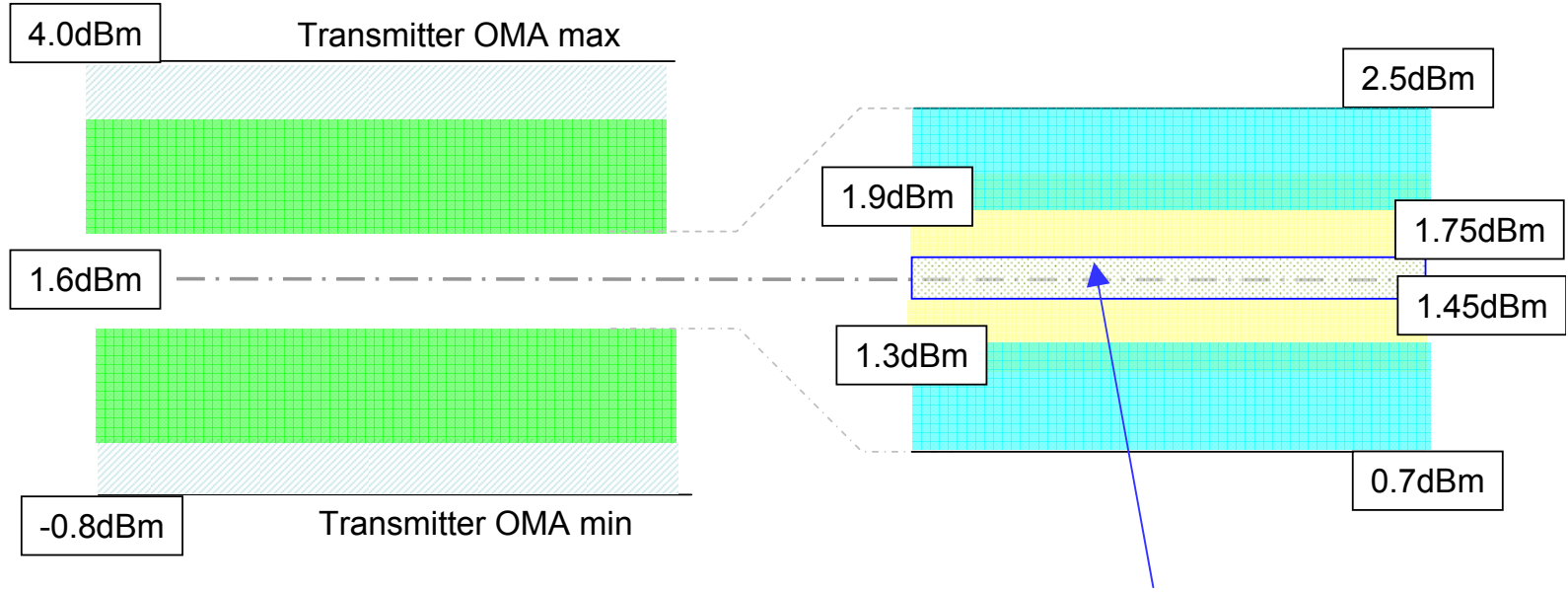| Description	100GBASE–LR4	Unit
Signaling speed per lane (range)	25.78125 ± 100 ppm	GBd
Lane wavelengths (range)	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19	nm
Receive power, per lane (OMA) (max)	4.0	dBm
Average receive power, per lane (max)	4.0	dBm
Damage threshold[a]	5.0	dBm
Average receive power, per lane[b] (min)	−10.1	dBm
Receiver reflectance (min)	−26	dB
Receiver sensitivity (OMA), per lane (max)	−8.1	dBm
Stressed receiver sensitivity (OMA), per lane[c]	−6.3	dBm
Vertical eye closure penalty,[d] per lane	1.8	dB
Receive electrical 3 dB upper cutoff frequency, per lane (max)	31	GHz

Launch OMA max :   4.0dBm
Launch OMA min :   -0.8dBm
Receive OMA min :   -8.1dBm

Level diagram per lane as per 100GBASE-LR4 baseline

| 4.0dBm | Transmitter OMA (max) | Receive OMA (max) |

Launch OMA range

Allocation for penalties
2.2dB

Transmitter OMA per lane (min)

-0.8dBm

-1.8dBm

Launch power in OMA-TDP (min)

Channel Insertion Loss
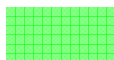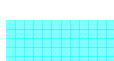6.3dB

-8.1dBm

Sensitivity OMA (max)

- ✓ The Transmitter launch OMA range is from -0.8dBm to 4.0dBm
- ✓ The range of 4.8dB is 1.66dB less than that in the 40GBASE-LR4.(See appendix)

Very narrow margin in Transmitter launch OMA for 100GBASE – LR4

			2.5dBm
4.0dBm	Transmitter OMA max		

1.9dBm

1.75dBm

1.6dBm

1.45dBm

1.3dBm

0.7dBm

-0.8dBm   Transmitter OMA min

Very narrow margin : 0.3dB

Assumptions

Power change over life (+/- 0.5dB)

Power change over the operation temp. in TOSA (+/- 1.0dB)

Maximum deviation of MUX insertion loss per lane from the typical value (+/- 0.6dB)
(Temperature dependence, PDL, power change because of LD wavelength drift)

Power change by mating/demating (+/- 0.15dB)

What is the issue in 100GBASE-LR4?

➢ According to the last foil, transmitter launch OMA should be set in between 1.45dBm and 1.75dBm.

➢ If EML based TOSAs are leveraged, the launch OMA might be set in this very narrow range with high cost. Because LD bias current of EA DFB just has to be adjusted precisely.

➢ However, it is difficult to build the DML-based TOSA into the transceiver because the modulation bandwidth (i.e. relaxation frequency) of laser diode related to its output power closely.

Relationship between relaxation frequency and output power

Assumptions:

$$P = \eta(I - I_{th})$$
$$f_r = \varsigma\sqrt{I - I_{th}}$$

- Output average power and relaxation frequency are proportional to "I-Ith" and square root of "I-Ith" , respectively.
- +/- 5% variance in slope efficiency (η) and in slope value of relaxation frequency (ς)
- IEEE PTL Vol.19, p1436 as a reference of typical value of η and ς. η=0.46W/A, ς=2.8GHz/mA$^{0.5}$
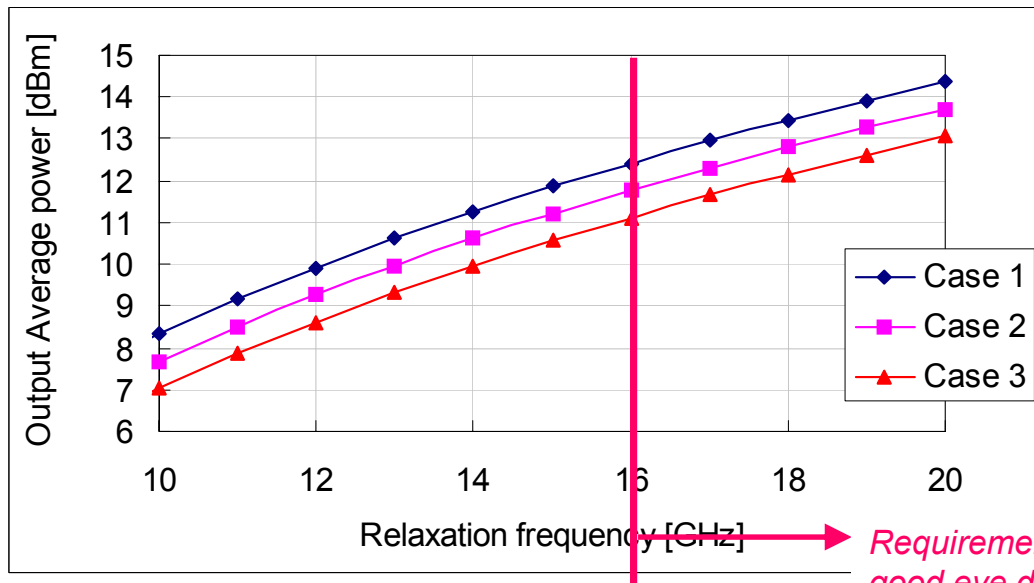
Case 1 : η(+5%), ς(-5%)
Case 2 : η(0%), ς(0%)
Case 3 : η(-5%), ς(+5%)

Requirement to achieve good eye diagram

Requirement for launch OMA margin
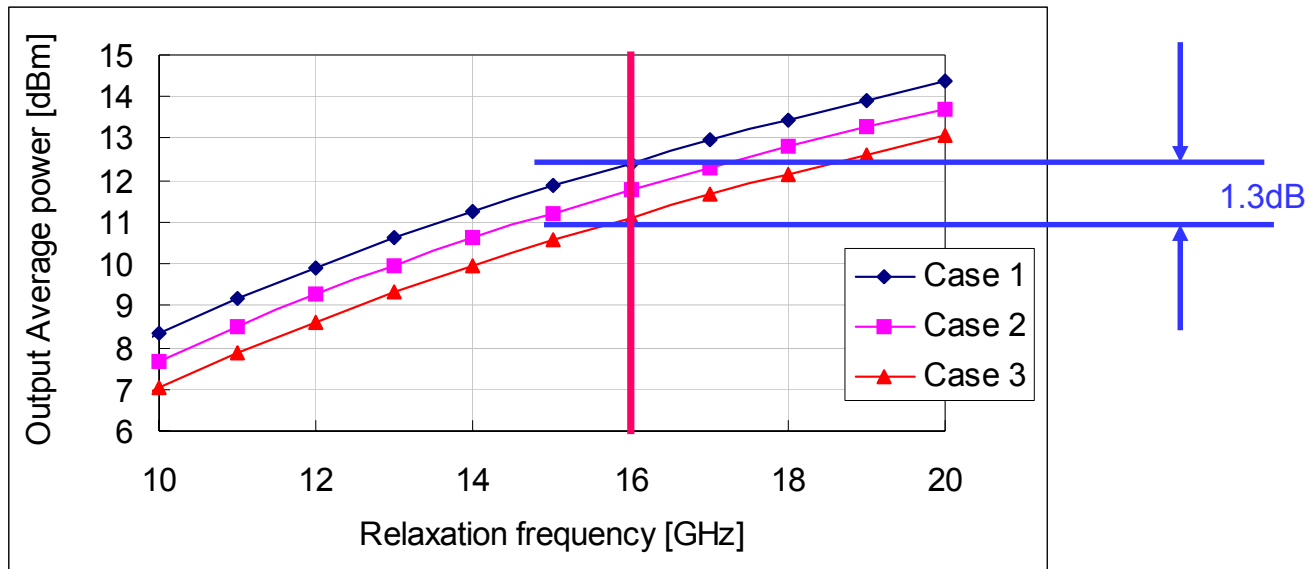
Assumptions:

- LD drive current is suppressed as much as possible in terms of low power consumption.
- Fixed optical coupling loss of TOSA regardless of the bandwidth of laser chip
- Same extinction ratio from the output in any case.

Launch OMA margin shall have more than 1.3dB if DML based 100GbE is taken into account. 1.0dB enhancement of OMA launch margin should be needed.

Remedy for this issue

- The comment is :
  - Transmitter launch OMA margin seems to be too narrow to have good yield. The root cause is located at the low launch OMA max and the low receive OMA sensitivity. The several numbers in Table 88-7 and 88-8 shall be modified.

- The remedy is :
  - Transmitter launch OMA max shall be changed from 4.0dBm to 4.5dBm
  - Transmitter Average launch (max) is changed from 4.0dBm to 4.5dBm
  - Receiver OMA sensitivity shall be changed from -8.1dBm to -8.6dBm

Receiver Overload

Assumptions:

- No splice loss and insertion loss of DEMUX.
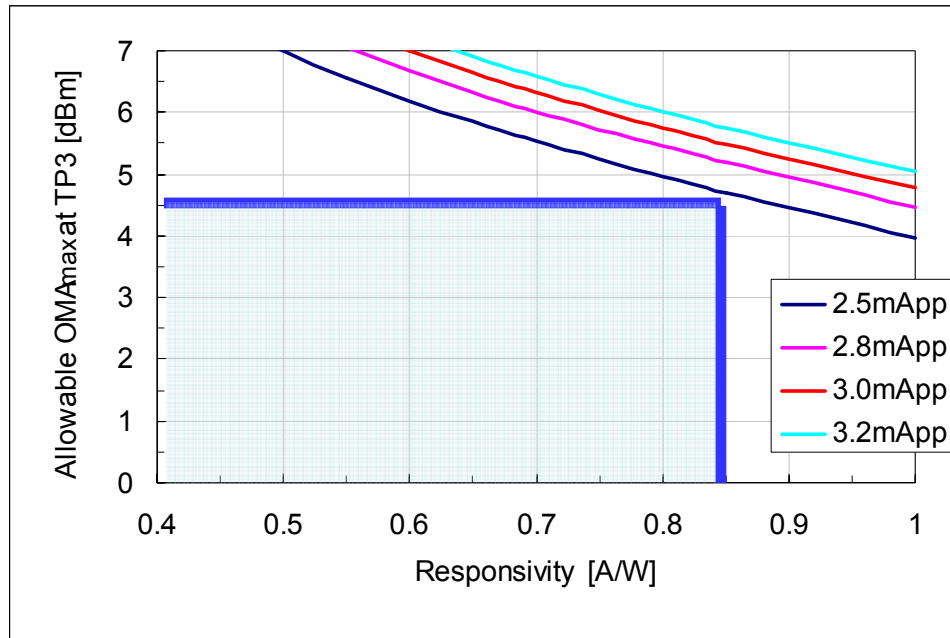
- ✓ If less than 0.85A/W of responsivity (max) and over 2.5mAp-p of input current to TIA (max) are assumed, The number of Receive OMA (max) can be changed to 4.5dBm with some margin.
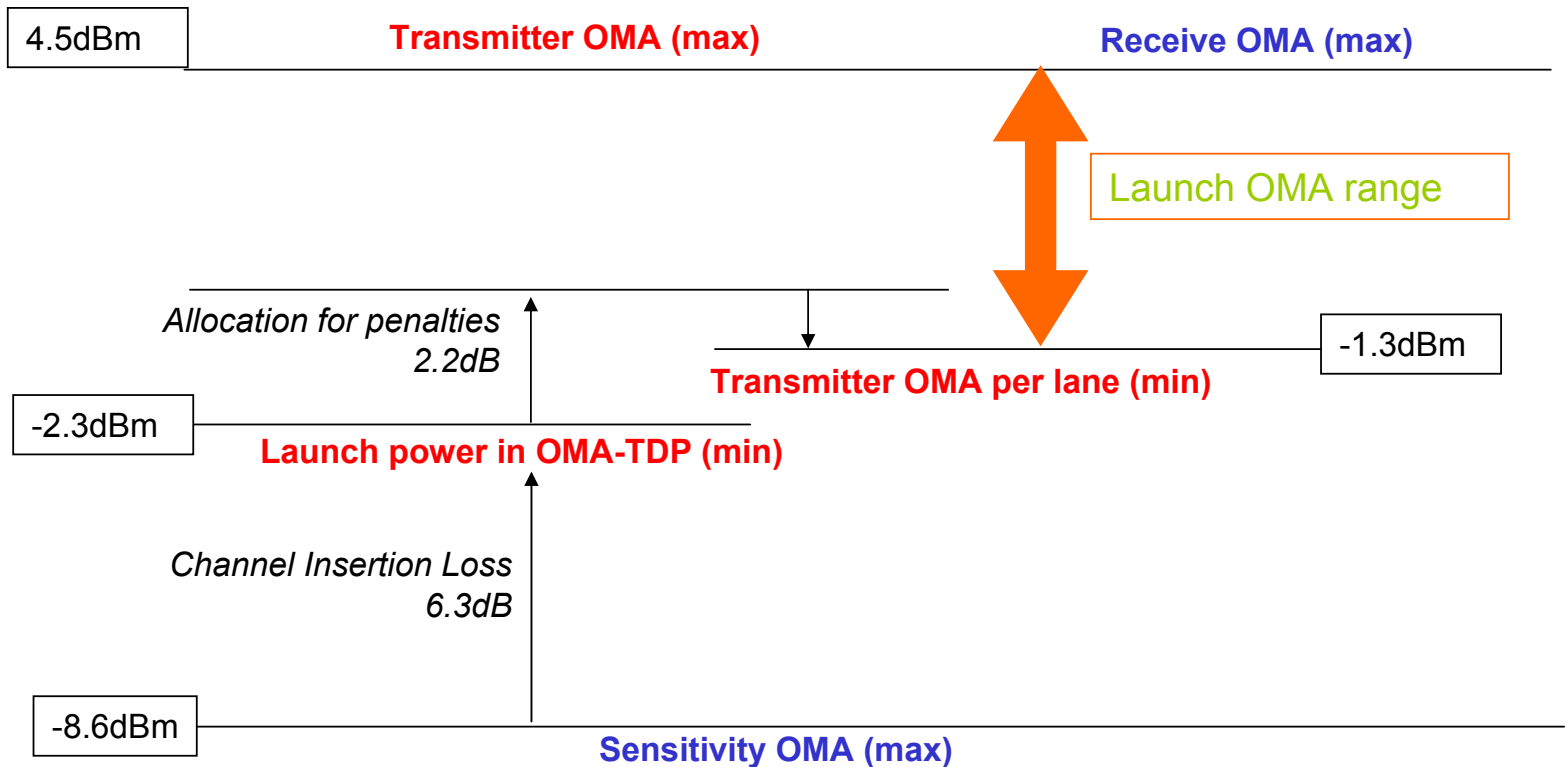
Receiver Sensitivity

Assumptions:

- Shot noise is ignored. (0.1dB degradation due to this factor)
- 0.55A/W of responsivity as the worst case.
- 20GHz of 3dB bandwidth.

-8.91dBm
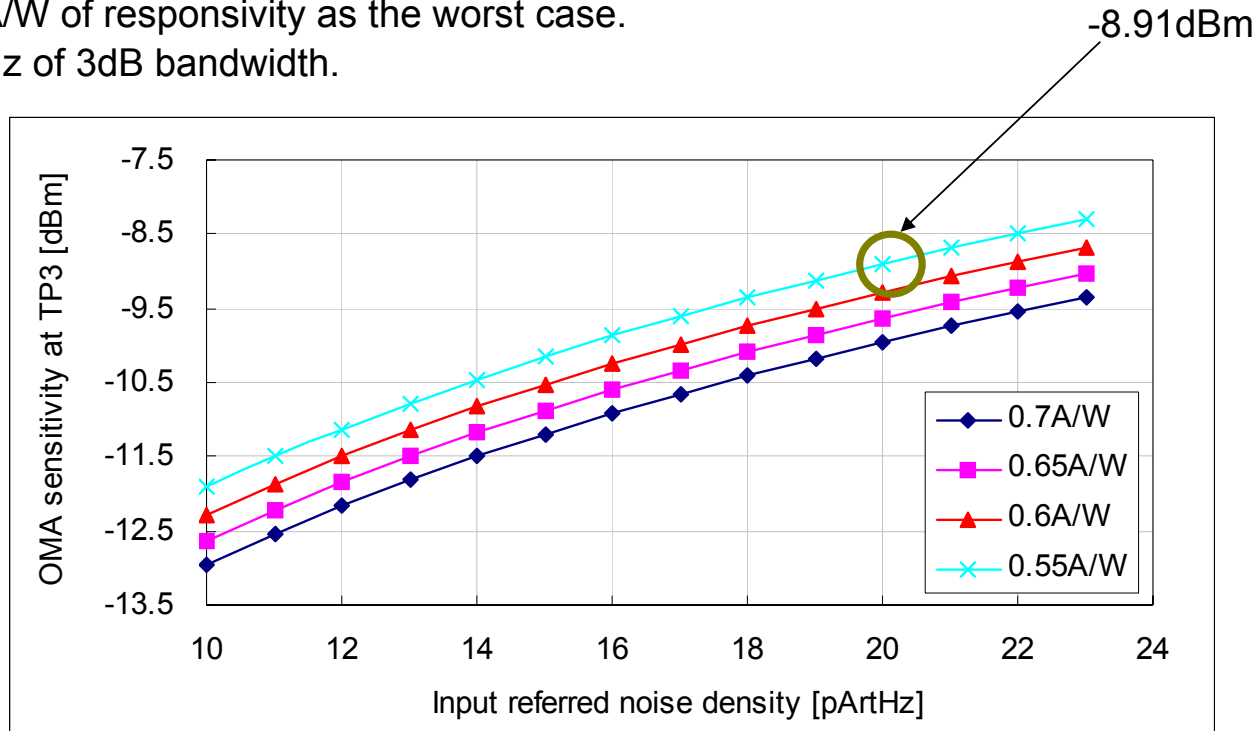
Less than 20pArtHz of input referred noise density is assumed, -8.6dBm of Receive sensitivity can be achievable even if 0.55A/W of responsivity

Level Diagram reflected the proposed remedies

4.5dBm — **Transmitter OMA (max)** — **Receive OMA (max)**

Launch OMA range

Allocation for penalties 2.2dB

Transmitter OMA per lane (min) — -1.3dBm

-2.3dBm — **Launch power in OMA-TDP (min)**

Channel Insertion Loss 6.3dB

-8.6dBm — **Sensitivity OMA (max)**

✓ The launch OMA range of 5.8dB is comparable to that in the 40GBASE-LR4.(See appendix)

✓ The values of several parameters in Table 88-7, 88-8 should be reviewed due to these remedies

Parameters required to change in Table 88-7 and 88-8

Description	100GBASE–LR4	Unit
Signaling speed per 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)	~~10.0~~ **10.5**	dBm
Average launch power per lane (max)	~~4.0~~ **4.5**	dBm
Average launch power per lane[a] (min)	~~−3.8~~ **-4.3**	dBm
Optical Modulation Amplitude (OMA), each lane (max)	~~4.0~~ **4.5**	dBm
Launch power per lane (min) in OMA minus TDP[b]	~~−1.8~~ **-2.3**	dBm
Optical Modulation Amplitude (OMA), each lane (min)	~~−0.8[c]~~ **-1.3**	dBm
Transmitter and dispersion penalty, each lane (max)	2.2 (See editors note)	dB
Average launch power of OFF transmitter, each lane (max)	−30	dBm
Extinction ratio (min)	4.0	dB
$RIN_{12}OMA$ (max)	−132	dB/Hz
Optical return loss tolerance (max)	12	dB
Transmitter reflectance[d] (max)	−12	dB
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3}	TBD	

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Lane wavelengths (range)	1294.53 to 1296.59 1299.02 to 1301.09 1303.54 to 1305.63 1308.09 to 1310.19	nm
Receive power, per lane (OMA) (max)	~~−4.0~~ **4.5**	dBm
Average receive power, per lane (max)	~~−4.0~~ **4.5**	dBm
Damage threshold[a]	~~−5.0~~ **5.5**	dBm
Average receive power, per lane[b] (min)	~~−10.1~~ **-10.6**	dBm
Receiver reflectance (min)	−26	dB
Receiver sensitivity (OMA), per lane (max)	~~−8.1~~ **-8.6**	dBm
Stressed receiver sensitivity (OMA), per lane[c]	~~−6.3~~ **-6.8**	dBm
Vertical eye closure penalty,[d] per lane	1.8	dB
Receive electrical 3 dB upper cutoff frequency, per lane (max)	31	GHz

Conclusion

➢ DML based 100GbE transceiver is attractive from the low cost and low power consumption view points. but the launch OMA margin which is calculated from Draft 1.0 is too narrow for the transceiver.

➢ This very narrow margin comes from the low launch OMA and low receive OMA sensitivity.

➢ The essential remedy for this issue is as following
  ➢ Transmitter launch OMA (max) each lane shall be changed to 4.5dBm
  ➢ Receiver sensitivity (OMA) per lane (max) shall be changed to -8.6dBm

➢ However, several parameters in Table 88-7 and 88-8 shall be also changed derivatively due to these remedies.

BACK UP

Parameters required to change derivatively by the remedies

The following parameters shall be changed derivatively in Table 88-7

1) Average launch power per lane (max)
   → According to 4.5dB of 'OMA each lane (max)' and the view point of the eye-safety, this number shall be changed to 4.5dBm

2) Total launch power (max)
   → According to 1), this number shall be changed to 10.5dBm

3) Launch power per lane in OMA minus TDP
   → According to the last slide, this number shall be changed to -2.3dBm

Parameters required to change derivatively by the remedies

The following parameters shall be changed derivatively in Table 88-7 (cont.)

4) OMA each lane (min)
- → According to the proposed level diagram, this number shall be changed to -1.3dBm

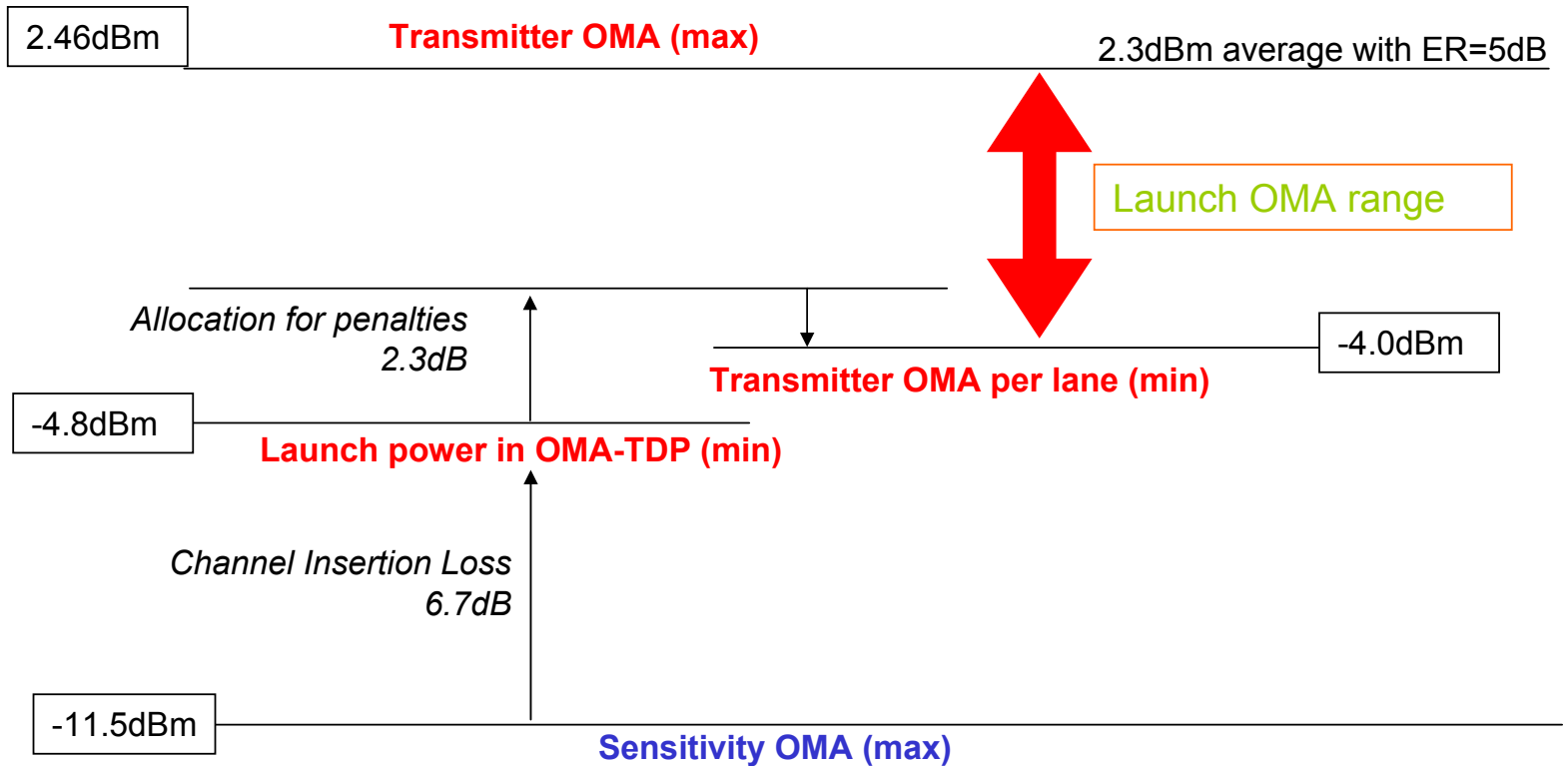The following parameters shall be changed derivatively in Table 88-8

1) Average receive power, per lane (max)
- → This number shall be as same number as 'Average launch power per lane (max)'. So, it shall be changed to 4.5dBm
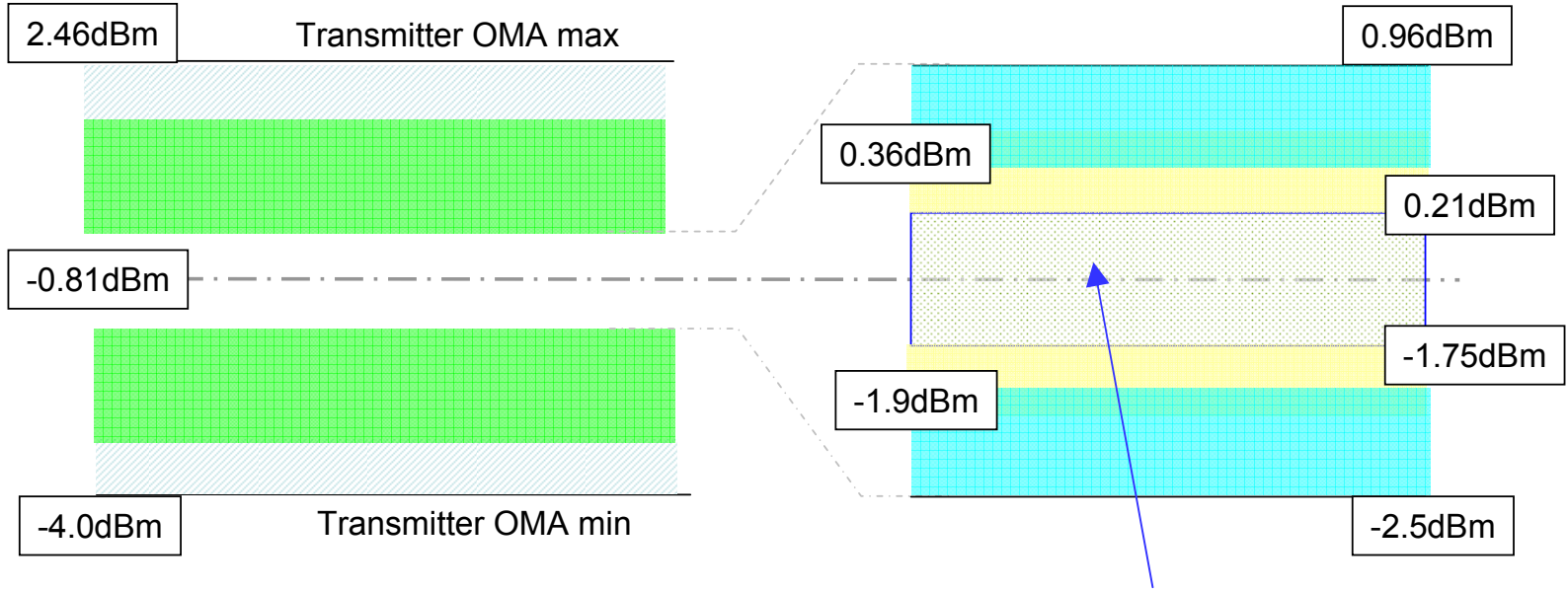
2) Damage Threshold
- → This number shall be changed to 5.5dBm. Before, at 5.0dBm threshold, this number is 1dB up from the average receive power, per lane (max)

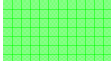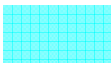# Level diagram per lane as per 40GBASE-LR4 baseline (ER=5.0dB)

2.46dBm — **Transmitter OMA (max)** — 2.3dBm average with ER=5dB

Launch OMA range

Allocation for penalties 2.3dB

-4.0dBm — **Transmitter OMA per lane (min)**

-4.8dBm — **Launch power in OMA-TDP (min)**

Channel Insertion Loss 6.7dB

-11.5dBm — **Sensitivity OMA (max)**

Margin in Transmitter launch OMA for 40GBASE – LR4

5.0dB of ER case

| 2.46dBm | Transmitter OMA max | 0.96dBm |

0.36dBm

0.21dBm

-0.81dBm

-1.75dBm

-1.9dBm

| -4.0dBm | Transmitter OMA min | -2.5dBm |

margin : 1. 96dB

Assumptions

Power change over life (+/- 0.5dB)

Power change over the operation temp. in TOSA (+/- 1.0dB)

Power change over the operation temp. in MUX module (+/- 0.6dB)

Power change by mating/demating (+/- 0.15dB)