WDM Alternatives for 100GE 40km SMF application

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HSSG 100GE 40km SMF application

- **Consensus to date on 40km SMF reach objective**
  - **For metro applications**
  - **4 X 26Gbps WDM architecture**
  - **DWDM grid with wide spacing (400 to 800GHz)**
  - **Transmitter with cooled EML**
  - **Receiver with PIN-PD and SOA pre-amplifier**

Technical Feasibility of 100GE Alternatives (WDM)
- 40km WDM spacing comparison-

WDM spacing	DWDM with wide spacing		CWDM (For reference)
	400GHz	800GHz	
Situation			
10km	Doable	Doable	Doable
40km	Doable	Doable	Unrealistic
Comparison			
Optics performance stability over temp.	Yes	Yes	Yes
RX interoperability between 10 and 40km	Yes	Yes	No
LD wavelength yield	Concerns	No problem	No problem
WDM OMUX size	Concerns	No problem	No problem
skew and dispersion	smallest	moderate	Too large for 40km
SOA	FWM non-linearity	Gain Slope/NF	Band Width

800GHz spacing may offer higher yield and lower cost!

Technical Feasibility of 100GE 40km Alternatives (WDM)
- 800GHz spacing possibility analysis procedure -

1. **Estimate the loss budget and Compare the Results with 400GHz spacing.**
   - ✓ **Edit and use the spread sheet "10GEPBud3_1_16a.xls" for 100GE.**

2. **Possibility of SOA for 800GHz spacing**
   - ✓ **SOA noise impact to the receiver sensitivity**
   - ✓ **SOA evaluation for each WDM spacing**
   - ✓ **Receiver sensitivity estimation**

3. **Summary**
   - ✓ **Summary**

Spread sheet edit for 100GE
- TX parameters -

400GHz Spacing: 1308.56nm,1310.85nm,1313.14nm,1315.45nm+/-0.36nm
800GHz Spacing:1304.01nm,1308.56nm,1313.14nm,1317.77nm +/-0.72nm

26Gbps X 4Lane

Assume the worst tr(20-80%) is 15ps

Assume –130dB/Hz

7dB is minimum Ext. ratio

Mask Proposal is Below.

Basics	Input=	**Bold**	Ts(20-80)	**15**	ps
	Q=	**7.04**	Ts(10-90)	23	ps
	Base Rate=	**25781.3** MBd	RIN(OMA)	**-130**	dB/Hz
Transmitter			RIN at MinER	-133.5	dB/Hz
Wavelength Uc		**1304.01** nm	RIN_Coef=	**0.70**	
Uw (see notes)		**0.0182** nm	Det.Jitter	**6.0**	ps inc. DCD
Tx pwr OMA=		**+3.08** dBm	DCD_DJ=	**6**	ps TP3
Min. Ext Ratio=		6.99 dB	Effect. DJ=	0.00	(UI) ex DCD
"Worst"ave.TxPwr		**1.83** dBm	MPN k(OMA)	**0**	
Ext. ratio penalty		1.76 dBo	Tx eye height	56.2%	
Tx mask	X1=	**0.3** UI	Refl Tx	**-12**	dB
	X2=	**0.4** UI	ModalNoisePen	**0**	dB
	Y1=	**0.25**	Tx mask top	0.2	UI

- ✓ **Other parameters are the same as 10GE.**
- ✓ **Compare the penalties and pick up the worst wavelength for each spacing.**
- ✓ **Regarding to the TX mask specification, our proposal is the same as 10GE. (X1,X2,X3,Y1,Y2,Y3)=(0.25,0.4,0.45,0.25,0.28,0.40)**

Spread sheet edit for 100GE
- Channel parameters -

Analyze for 40km application

Use unit loss because this is DWDM

Case:	1310nm 40 km	**SMF**	Attenuation=	**0.4**	dB/km
Target	Target reach	**40.00** km	*Fiber* at	1310	nm
and	L_start=	**30.0** km	C_att=	0.27	
graph	L_inc=	**1.0** km	Attenuation=	0.40	dB/km
	Power Budget P=	23.01 dB	at	1315.46	nm
	Connections C	**2** dB	Disp. min. Uo=	**1300**	nm
	Pwr.Bud.-Conn.Loss	21.01 dB	Disp. So=	**0.093**	ps/nm^2*km
	C1=	**480** ns.MHz	Disp. D1=	1.41	ps/(nm.km)
	Reflection Noise factor	**0.6** no units			
	Effective Rate	30499 MBd	PolMD DGDmax	**12**	ps at target 40km
	Tb_eff=	33 ps	BWm=	**1E+06**	MHz*km
	Effective Rec Eye	0.24 UI	Eff. BWm=	1.1E+06	MHz*km

0.3UI

- ✓ **Regarding to the DGD, we refer to the SONET specifications Supplement 39 to the G Series of ITU-T Recommendations**

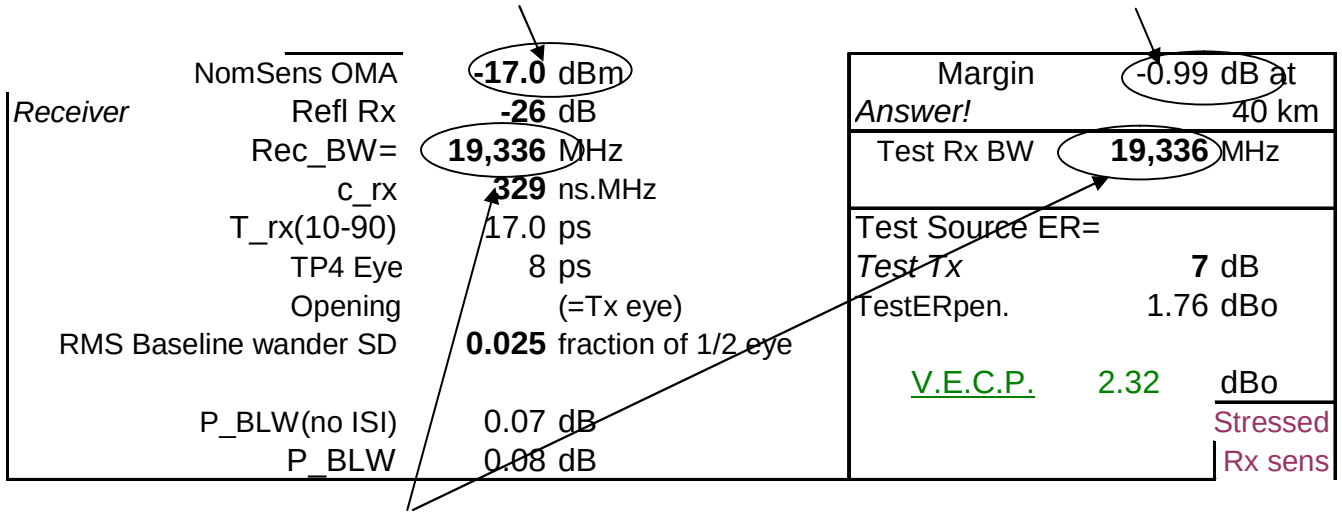
"9.3 Polarization-mode dispersion
For NRZ transmission up to 40 Gbit/s, the maximum DGD is set to 30% of the bit period,corresponding to a maximum 1-dB path penalty. "

- ✓ **PDL(PDG) of WDM filters and SOA is around 0.2dB. It may be negligible.**

Spread sheet edit for 100GE
- RX parameters -

Assume the PIN_PD sensitivity, SOA gain and SOA penalty(NF,FWM) (refer to P15 in detail.)

Tune the Transmitter power in OMA at the value of Margin=0dB.



Set the receiver BW=25.781GHz X 0.75

Technical Feasibility of 100GE 40km Alternatives (WDM)
- 40km WDM spacing comparison-

WDM Spacing	DWDM		Reference	
	400GHz	800GHz	10GbaseER	
Target Reach	2 to 40km	2 to 40km	2 to 30km	2 to 40km
Chromatic Dispersion(ps/nm)	-60ps/nm 58ps/nm	-79ps/nm 67ps/nm	546ps/nm	728ps/nm
max DGD(ps)	12ps	12ps	19ps	
max skew between CHs(ps)	344ps	754ps		
Max.CH Insertion Loss(dB)	18dB	18dB	10.9dB	10.9dB
Penalties (dB)	3.0dB	3.1dB	3.6dB	4.1dB
Power Budget (dB)	21.0dB	21.1dB	15.0dB	

- ✓ Use anslow_02_0107.xls for Skew and Dispersion calculation.
- ✓ Reasonable dispersion penalty (<2dB) may be expected with -79 and 67ps/nm dispersion.
- ✓ Max. skew 754ps is under the maximum skew level discussed in HSSG.
- ✓ Power budget for 400GHz and 800GHz spacing are nearly identical.

Technical Feasibility of 100GE 40km Alternatives (WDM)
- 800GHz spacing possibility analysis procedure -

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2. **Possibility of SOA for 800GHz spacing**
   - ✓ **SOA noise impact to the receiver sensitivity**
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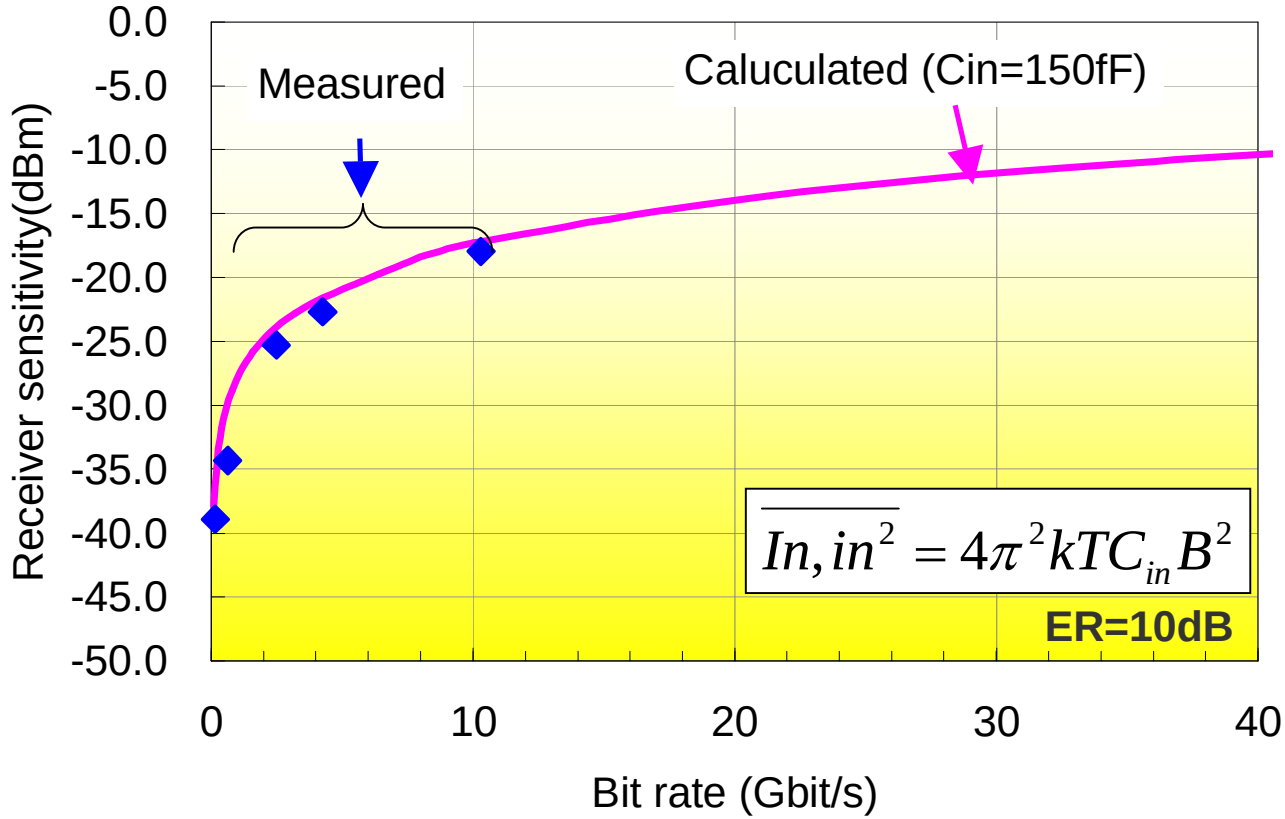
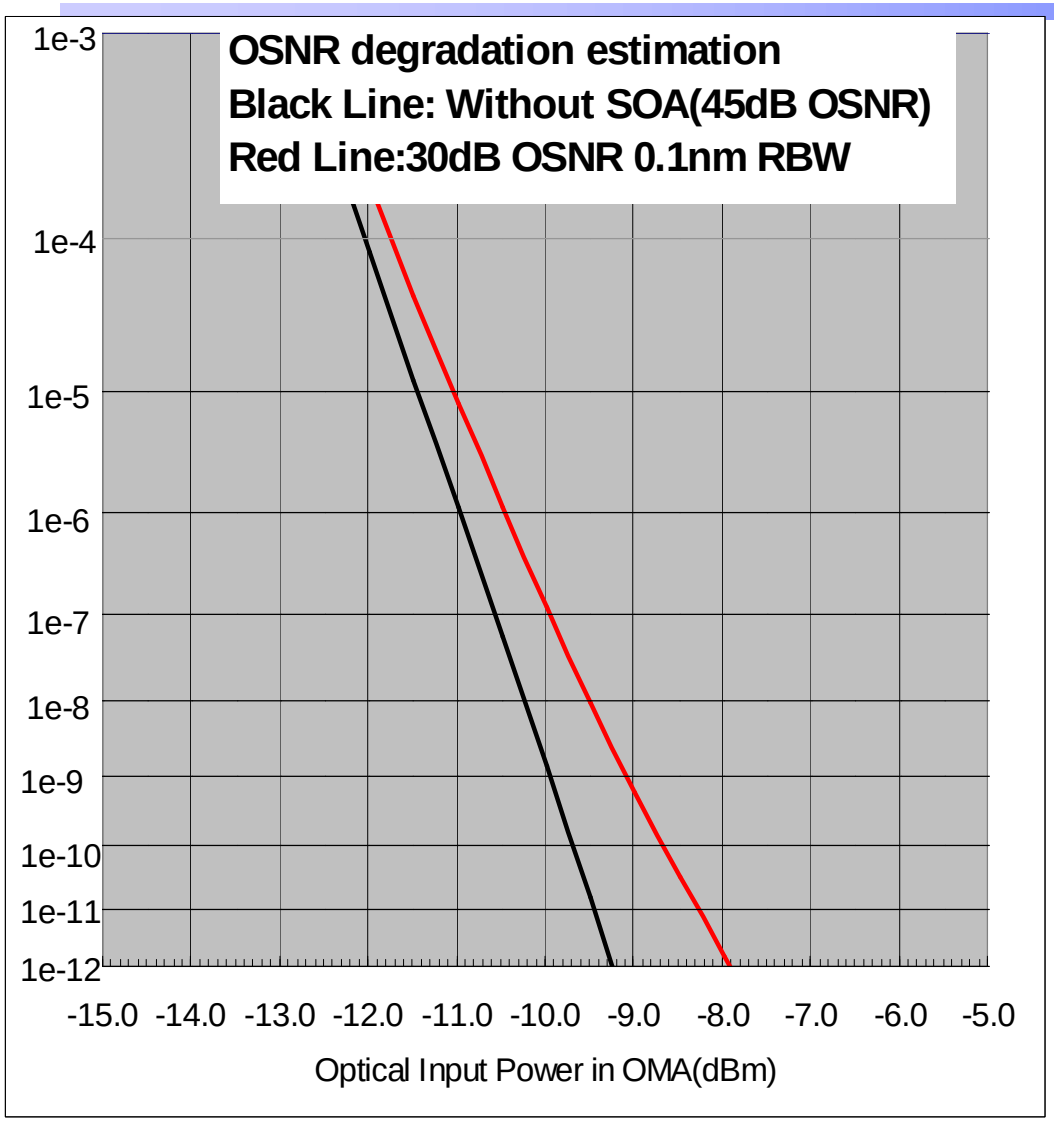
3. **Summary**
   - ✓ **Summary**

SOA noise impact to the receiver sensitivity -PIN-RX parameter estimation -



- ✓ **Estimate the receiver sensitivity with the formula above at 25deg.C.**
- ✓ **Good correlation was observed.**
- ✓ **We estimate that the noise current at 85deg.C is 4.5uArms for 26Gbps TIA.**

SOA noise impact to the receiver sensitivity
-SOA noise impact -



Estimation of receiver sensitivity degradation by OSNR

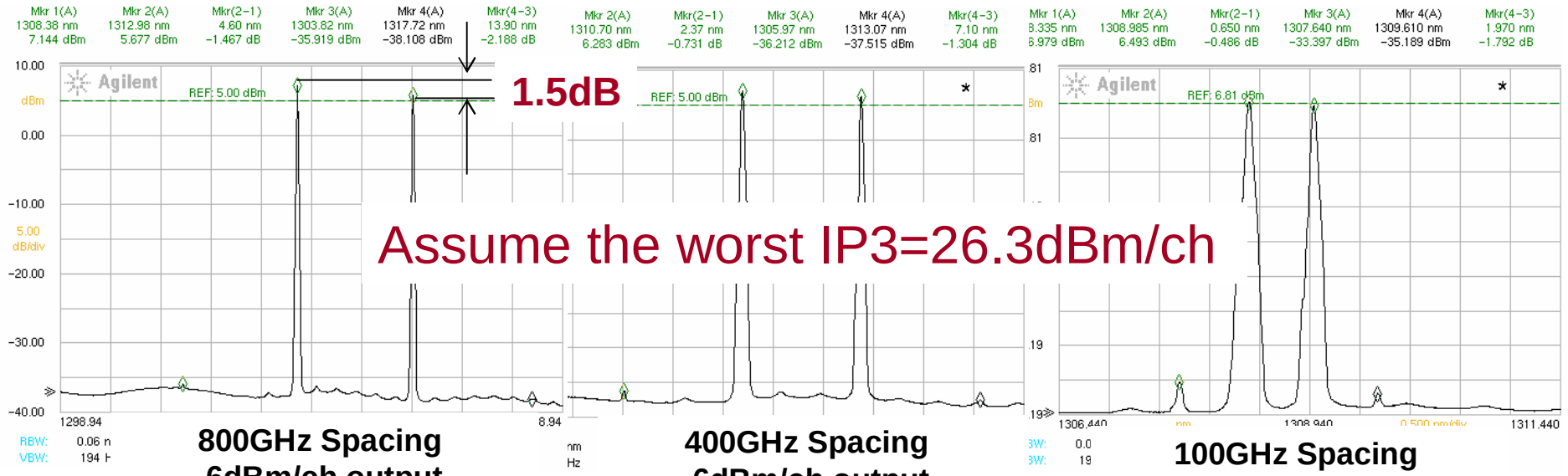
Assumptions

Base Rate:	25781.25MBd
PD sensitivity:	0.6A/W
Input noise current :	4.5uArms
Dark Current:	1nA
Receiver BW:	19336MHz
Temp. of RX:	85 deg.C
NF of SOA:	7dB
SOA input:	-17dBm

✓ **The OSNR(30dB) penalty is estimated at around 1.5dB.**

SOA non-linearity evaluation
-2-tone measurement-

SOA 2-tone distortion test results



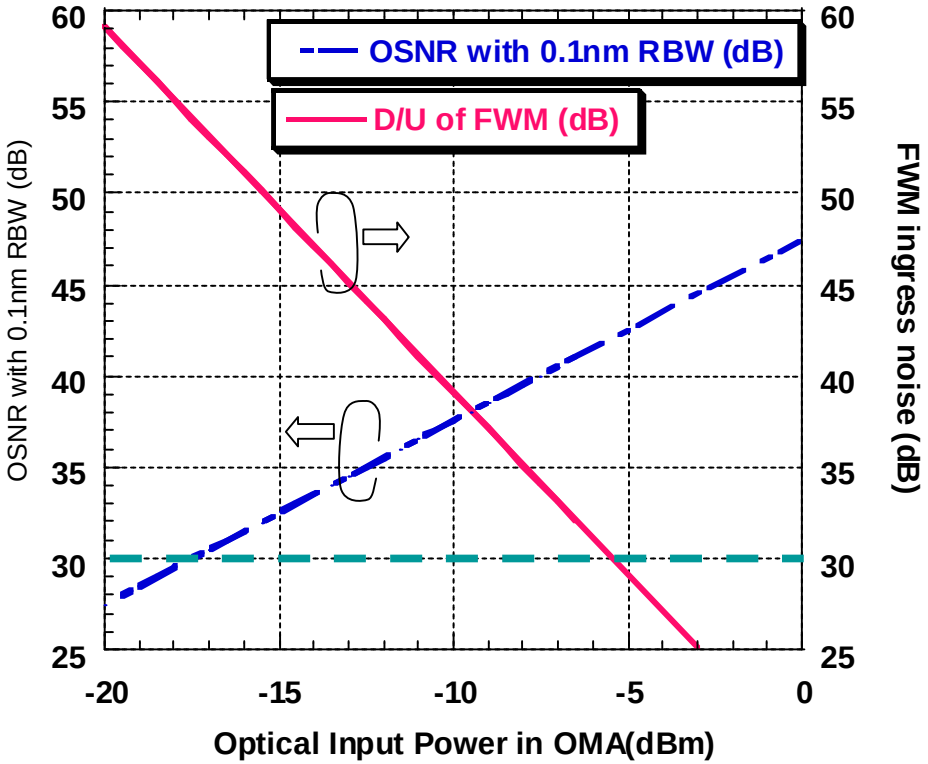
800GHz Spacing
6dBm/ch output
(Under measurement limit)
D/U>43dB(2-tone)

400GHz Spacing
6dBm/ch output
(Under measurement limit)
D/U>43dB(2-tone)

100GHz Spacing
6dBm/ch output
D/U=41dB(2-tone)
D/U>33dB(4ch estimation)

- ✓ **Currently available SOA shows promising non-linear performance results ,even with 400 and 800GHz spacing.**
- ✓ **1.5dB gain difference was observed between 2channels with 800GHz spacing . 5dB gain slope is estimated over 4channels of 800GHz spacing.**

Detailed estimation of Receiver
- SOA performance estimations-



Assuming
NF of SOA is 7dB
IP3 of SOA is 26.5dBm/ch

- ✓ **Further study is required for the impact of non-linear (FWM) ingress noise to the transmission performance.**
- ✓ **With regard to the OSNR and FWM ingress noise, 30dB D/U may be expected over –5.5 to –18dBm input range with currently available SOA.**

Receiver sensitivity estimation

Items	Worst value	Note
Maximum Rx sensitivity (dBm)	-17.0	Per lane.
Minimum SOA Gain at Maximum Rx sensitivity (dB)	15	Per lane. Must consider gain slope, Psat(4ch) of SOA.
ODMUX Loss max(dB)	4.0	Including the coupling losses and filter Loss
PIN_RX sensitivity with SOA in OMA(dBm)	-6.0	PIN_RX sensitivity w/o SOA in OMA+ SOA penalty
SOA penalty for minimum sensitivity (dB)	3.0	OSNR @ 0.1nm BW: 30dB (NF:7dB) FWM ingress noise :30dB
PIN_RX sensitivity w/o SOA in OMA(dBm)	-9.0	Reference Noise current is 4.5uArms at 85deg.C

- ✓ Under the estimation that the 30dB D/U from ingress noise would give another 1.5dB degradation of sensitivity, 40km receiver sensitivity would be estimated above.
- ✓ Further study is required for the impact of non-linear (FWM) ingress noise to the transmission performance.
- ✓ Further improvement is required for the gain slope and dynamic range of SOA.

Optical Link specification example
- 800GHz spacing DWDM for 40km application-

Items		2 to 40km	10GbaseER
TX	Average launch power (max) per lane	5.5dBm	4.0dBm
	Average launch power (max) All lanes	11.5dBm	
	Optical Modulation Amplitude (min) per lane	2.5dBm	-1.7dBm
	Launch power (min) in OMA minus TDP per lane	2.1dBm	-2.1dBm
	Transmitter and dispersion penalty (max) per lane	2.0dB	3.0dB
	Extinction Ratio(min)	7.0dB	3.0dB
CH	Channel insertion loss(min)	10.0dB	5.0dB
	Power budget (max)	21.1dB	15.0dB
RX	Average receive power (max) per lane	-4.5dBm	-1.0dBm
	Average receive power (max) all lane	1.5dBm	
	Stressed receiver sensitivity in OMA (max) per lane	-14.7dBm	-11.3dBm
	Receiver sensitivity (max) in OMA per lane	-17.0dBm	-14.1dBm

✓AEL Class1 eye safety limit @ 1310nm is 12dBm.

Technical Feasibility of 100GE 40km Alternatives (WDM)
- 40km WDM spacing comparison summary-

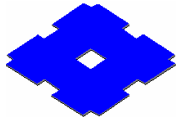
1. Comparison summary

- ✓ From the Loss budget estimation and SOA evaluation, we could observe the possibility of 800GHz spacing for the 100GE 40km transmission.
- ✓ We could expect higher yield and lower cost with 800GHz spacing than 400GHz spacing.
- ✓ Loss budget for 400GHz and 800GHz spacing are nearly identical.

2. Technological Issues

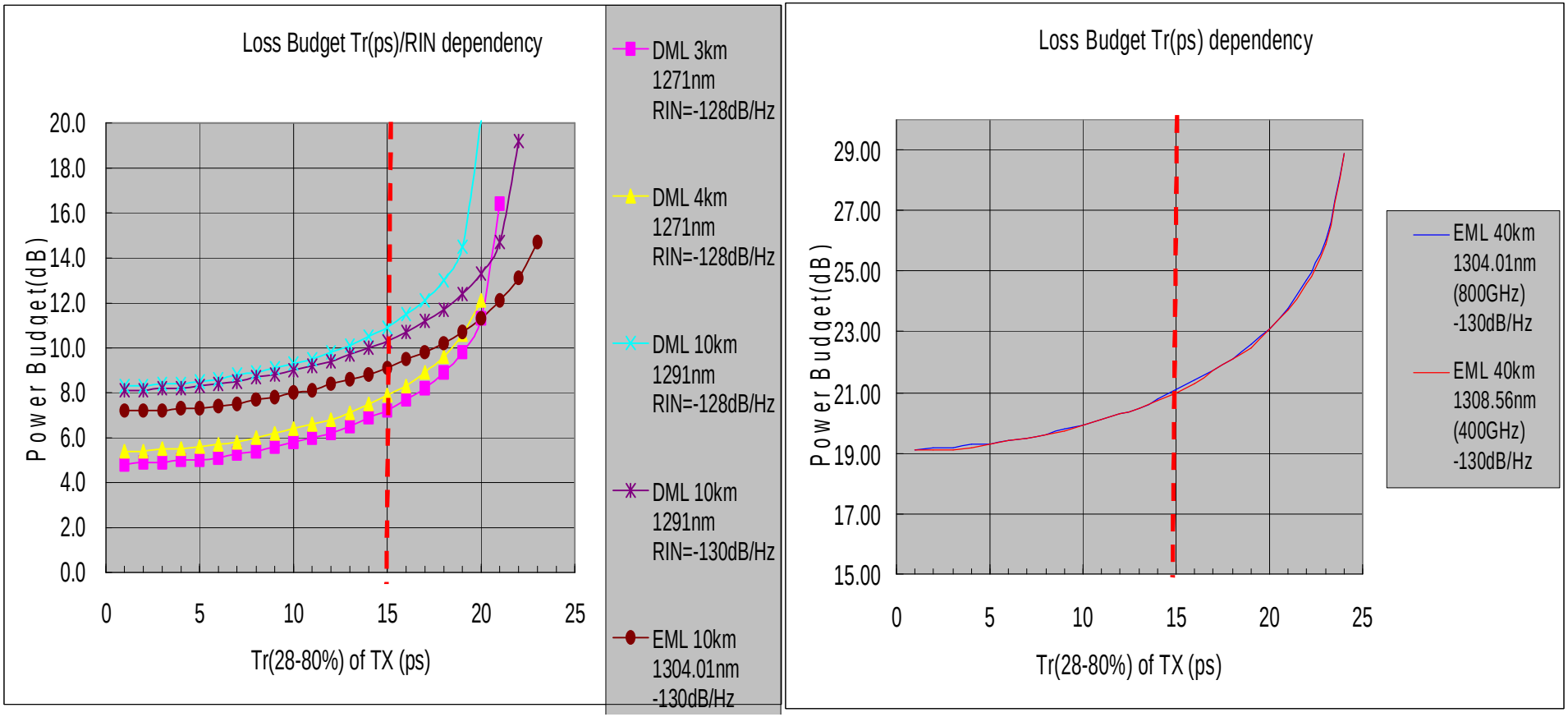
- ✓ Gain slope (estimated around 5dB over 800GHz spacing wavelength range) and dynamic range of SOA need to be improved. Further investigation is required for improvement.

Could not find any fatal issues for 800GHz WDM spacing !



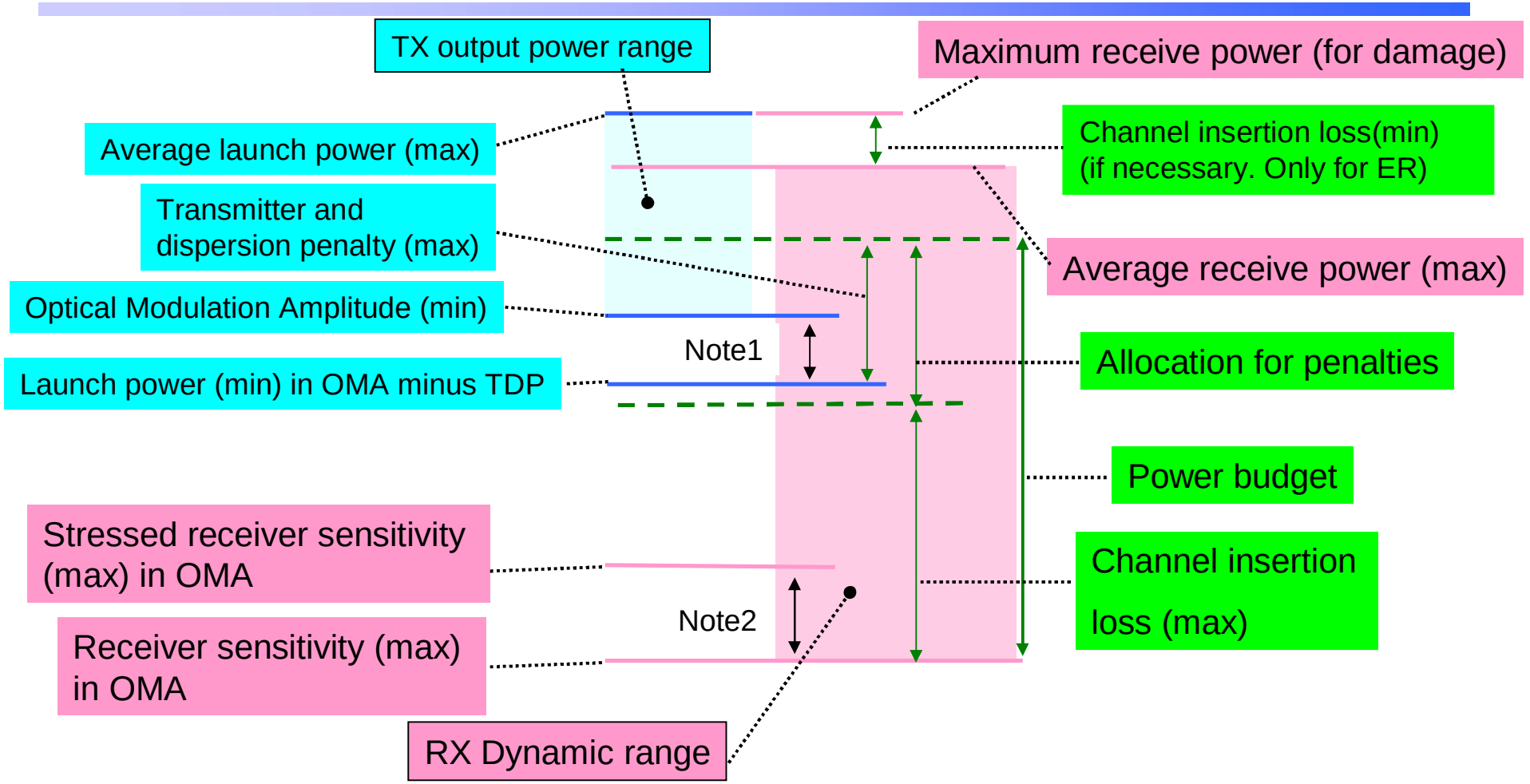
Thank You!

Spread sheet edit for 100GE
- TX parameters analysis -



- ✓ **Power Budget depends on Ts and RIN(OMA) value.**
- ✓ **In this material, we use Ts=15ps and RIN=-130dB/Hz for EML transmitter as start point.**

Link Budget of IEEE802.3ae 10GE



Note1:Even if the TDP < 0.4 dB for ER and <1.0dB for LR, the OMA(min) must exceed this value.
These number came from the margin against the triple trade offs and fiber loss slope in the wavelength range.
Note2:The sensitivity difference between Stressed and non-stressed is given as VECP(ISI related penalty).

Link Budget of SONET