

Super-PON Link Budget Analysis

IEEE P802.3cs, April 2, 2020
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Link budget required for 50-km link

Highlighted optical component losses were revised down to represent *premium* grade components to help reduce the very challenging objectives

Component	count	typical loss [dB]	worst case loss [dB]	Total loss [dB]	comments
Fiber [km]	50	0.24	0.24	12	Revised numbers from Vince (Corning)
Connectors	6	0.2	0.5	1.5	Count from Hawaii meeting (11/19)
Splices	17	0.05	0.2	1	7 for components/cable changes, 10 for inline
AWG	1	4	4	4	5.5 dB from previous contributions. -1.5 dB for MZI to reduce IL
Splitter (x64)	1	20.5	20.5	20.5	Assumes 3.5 dB per 2x -0.5 dB. Premium splitters assumed
Aging Margin	1	2	2	2	Industry practice
Total				41	

Change from 2019-11 - Waikoloa

Component	count	typical loss [dB]	Total from 2019-11 [dB]	Total proposed 2020-04 [dB]	comments
Fiber [km]	50	0.24	12	12	Revised numbers from Vince (Corning)
Connectors	6	0.2	1.5	1.5	Count from Hawaii meeting (11/19)
Splices	17	0.05	1	1	7 for components/cable changes, 10 for inline
AWG	1		4.8	4	Revised from (6.3-1.5) dB to (5.5-1.5) dB. Vendor with highest loss estimate revised specification.
Splitter (x64)	1		21.5	20.5	Assumes 3.5 dB per 2x -0.5 dB. Premium splitters.
Aging Margin	1		0	2	Industry practice
Total			40.8	41	

Link budget required for 40-km link

For a 40-km link, the reduced loss associated with fiber transmission can be given back to the splitter and AWG, avoiding the need for premium components

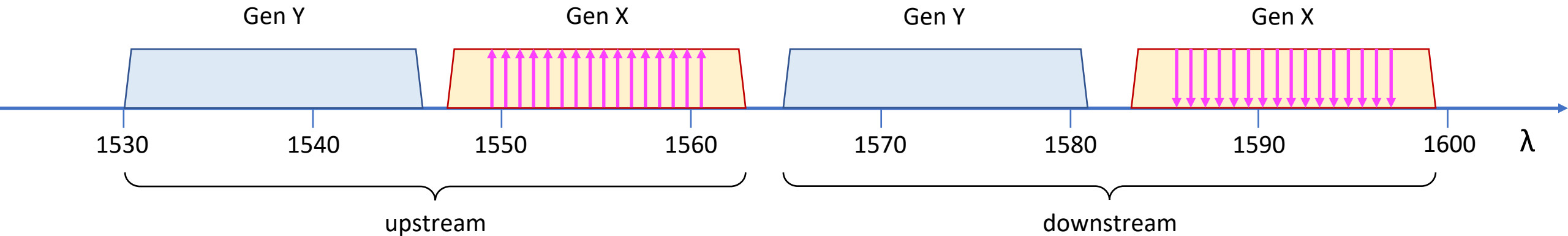
Component	count	typical loss [dB]	worst case loss [dB]	Total loss [dB]	comments
Fiber [km]	40	0.24	0.24	9.6	2.4 dB less
Connectors	6	0.2	0.5	1.5	
Splices	17	0.05	0.2	1	
AWG	1	5.5	5.5	5.5	Standard AWG loss
Splitter (x64)	1	21	21	21	Assumes 3.5 dB per 2x, standard for splitters
Aging Margin	1	2.4	2.4	2.4	0.4 dB more than the 50 km case
Total				41	

Assumptions (Rx sensitivity and TDP)

	2020-1	2020-04
TDP US [dB]*	0	2.1
TDP DS [dB]	0	1.1
ONU Rx power [dBm]**	-32	-31
OLT Rx Power [dBm]***	-39.7	-39.1

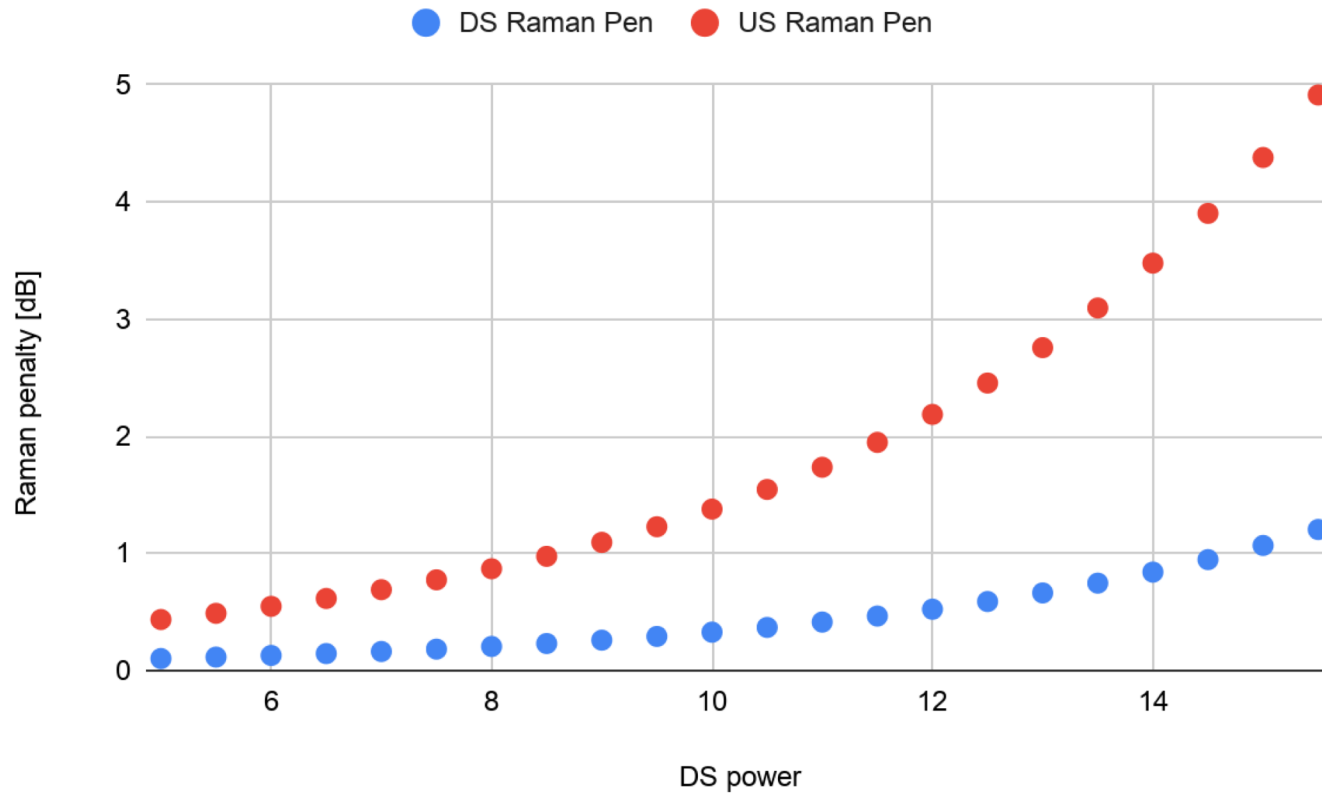
- * US sensitivity refers to the power into the bidi unit after the optical amplifiers. This is a part of the mux/amp unit
- ** 1.5 dB better than PR40 sensitivity for 10G-EPON. 1.5 dB benefit was recommended for LDPC FEC in [powell_3ca_1b_0118](#)
- *** From interpolation of results shown in [20190521_Zhao](#), with 0.6 dB reduction to account for burst-mode transmission

Assumed wavelength plan



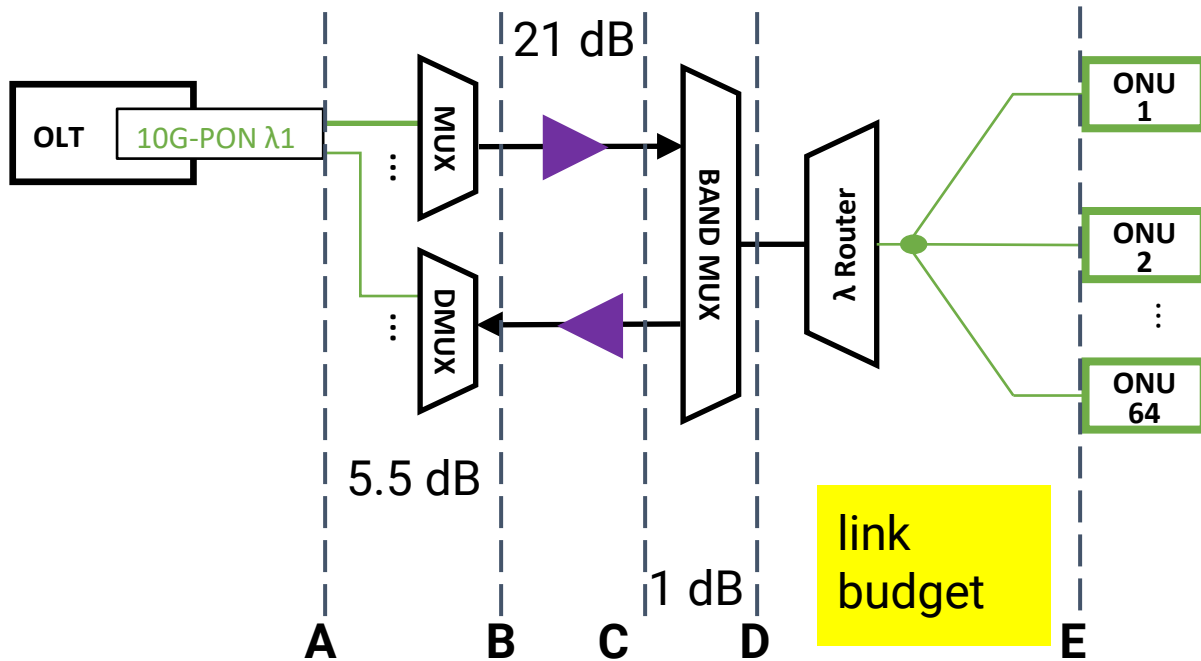
- Just calculating for Raman in current 10G generation
- Assume all DS channels are launched at the same power

Raman penalty: DS in L; US in C



- Numerically solving the Raman penalty ODE produced this penalty graph
- Exact wavelengths are given in slide 7 of [20190312_Ogawa](#)
 - This is the adopted baseline wavelength plan, as shown in Table 200-4 of [D0.5](#).
- This curve is used to calculate Raman power penalties for results in this deck

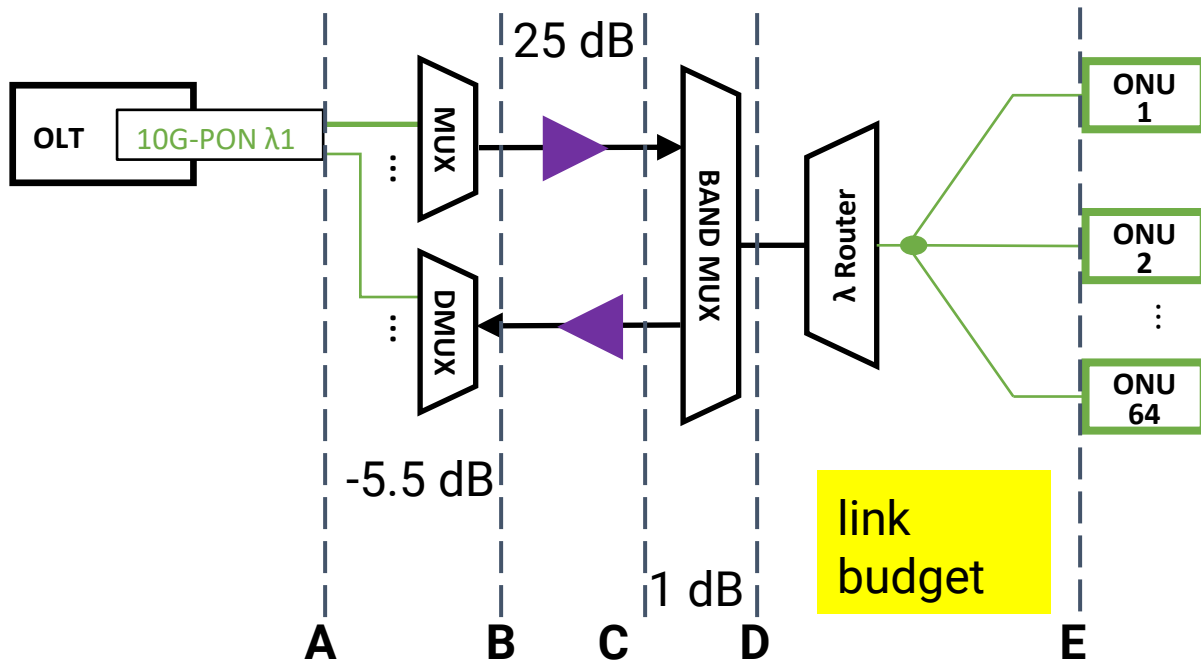
Power levels - DS



- Pow DS is defined as the power exiting the mux/amp
- This is the last active equipment before the signal enters the ODN
- Link budget accounts for maximum transmission penalties, including 1-dB for CD and Kerr NL, and the calculated amount for Raman

Location	DS/WL [dBm]	DS total [dBm]
A	PowDS-14.5	
B	PowDS-20	PowDS-8
C	PowDS+1	PowDS+13
D	PowDS	PowDS+12
E	-31 (PR40 -1.5)	

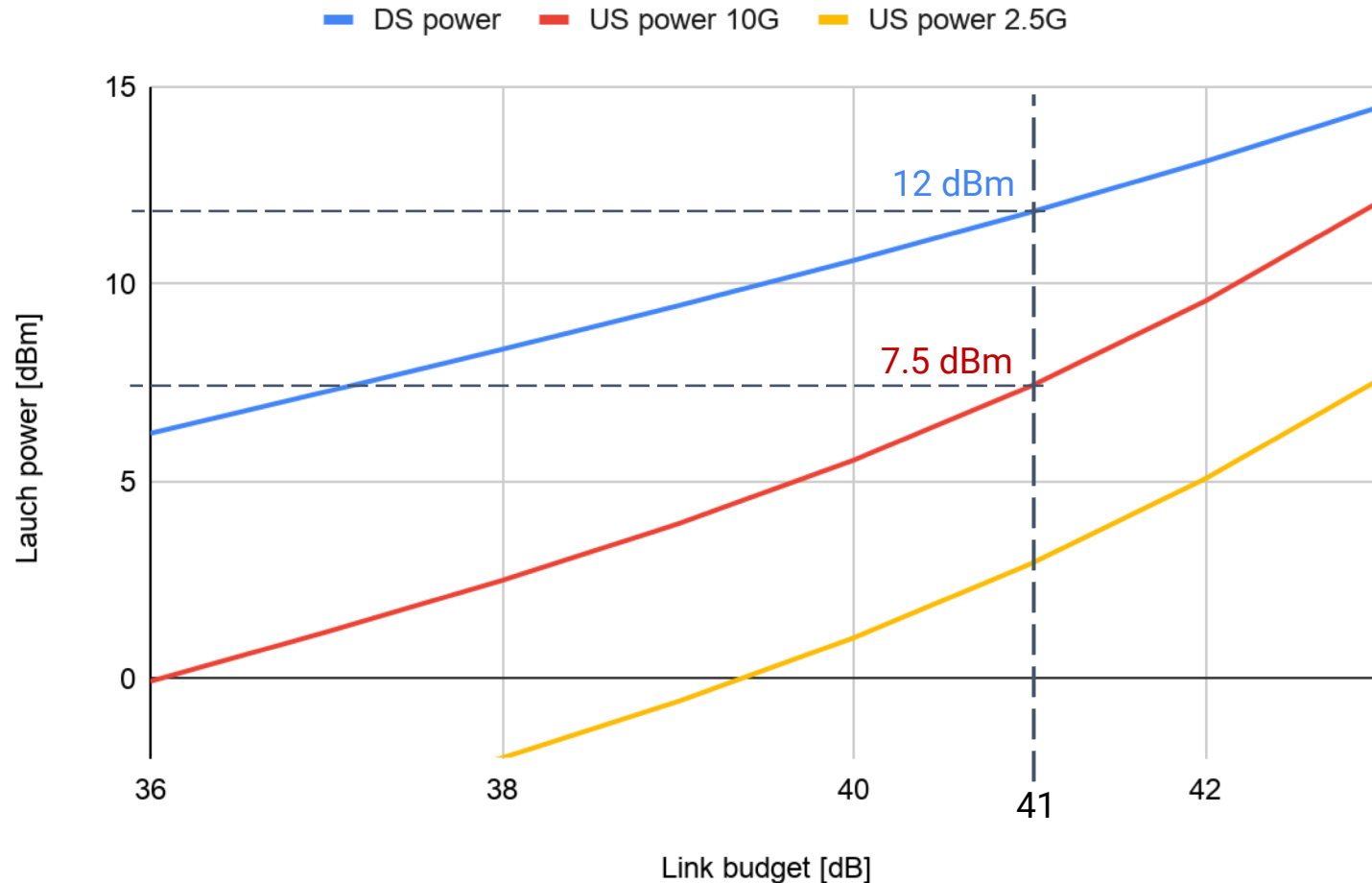
Power levels - US



- PowUS is defined as the power exiting the ONU
- US sensitivity is defined as the power needed at the mux/amp - ODN interface
- Link budget accounts for maximum transmission penalties, including 2-dB for CD and Kerr NL, and the calculated amount for Raman

Location	US/WL [dBm]	US total [dBm]
A	-20.6	
B	-15.1	-3.1
C	-40.1	-28.1
D	-39.1	-27.1
E	PowUS	

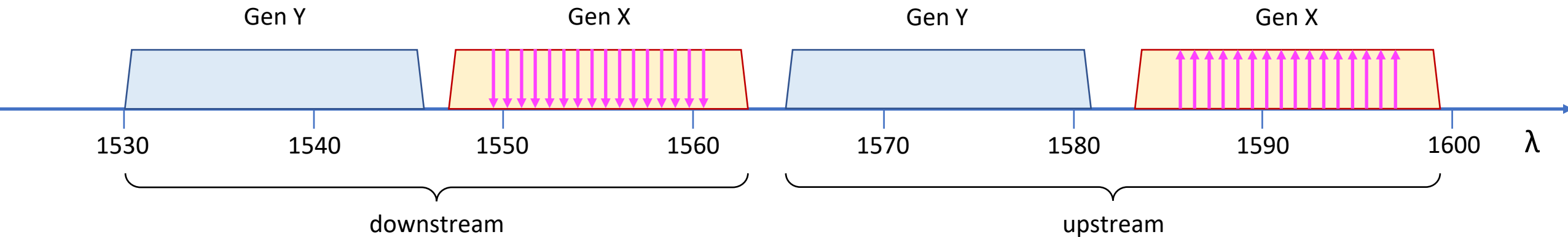
Required output power



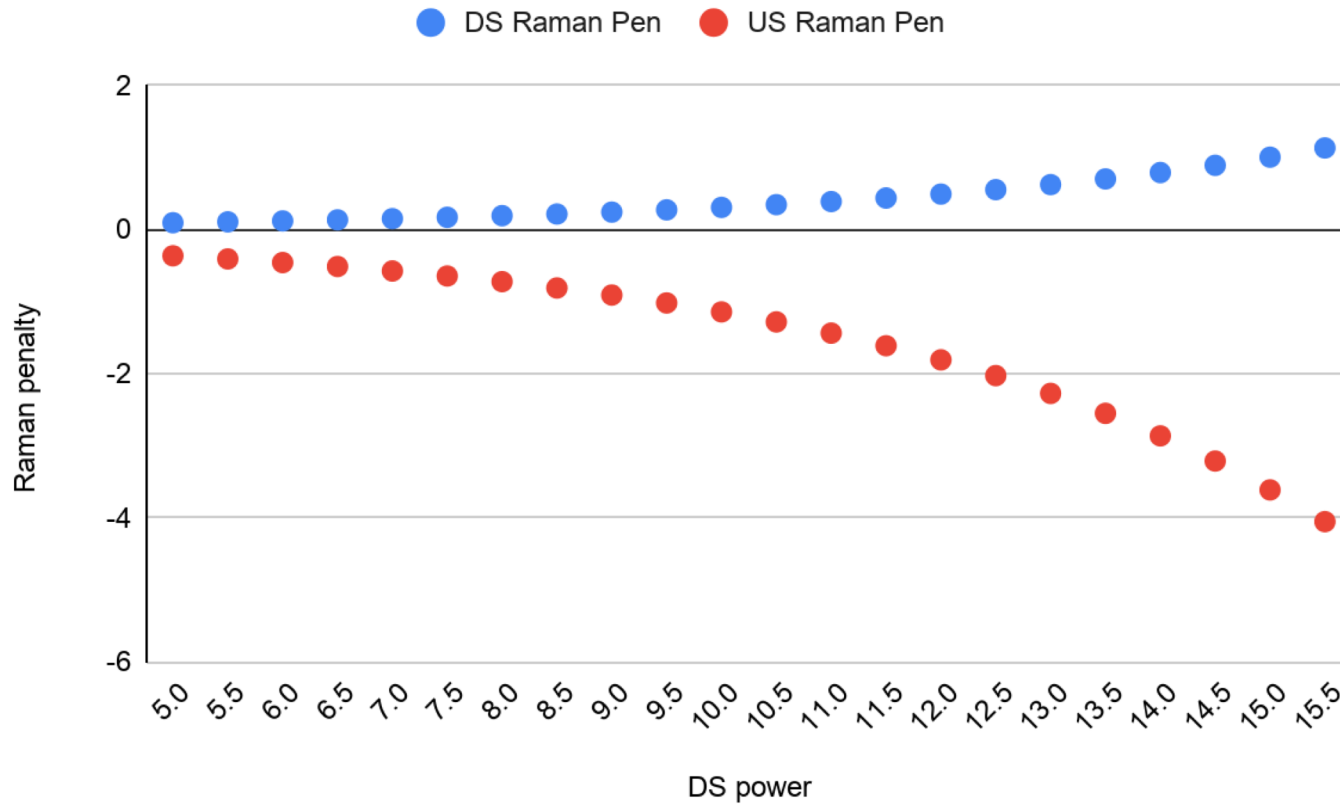
- The required US and DS output power is shown in the graph
- Raman penalty is based on $\text{min_DS_power} + 2 \text{ dB}$
 - Accounts for the DS not being installed at lowest possible power for all channels
- $>3 \text{ dB}$ of Raman penalty leads to $>7 \text{ dBm}$ of ONU output power

Proposal: Use C-band for DS and L-band for US

- Placing the higher powered DS channels on shorter wavelengths (relative to US channels) produces Raman gain on the US channels, rather than loss

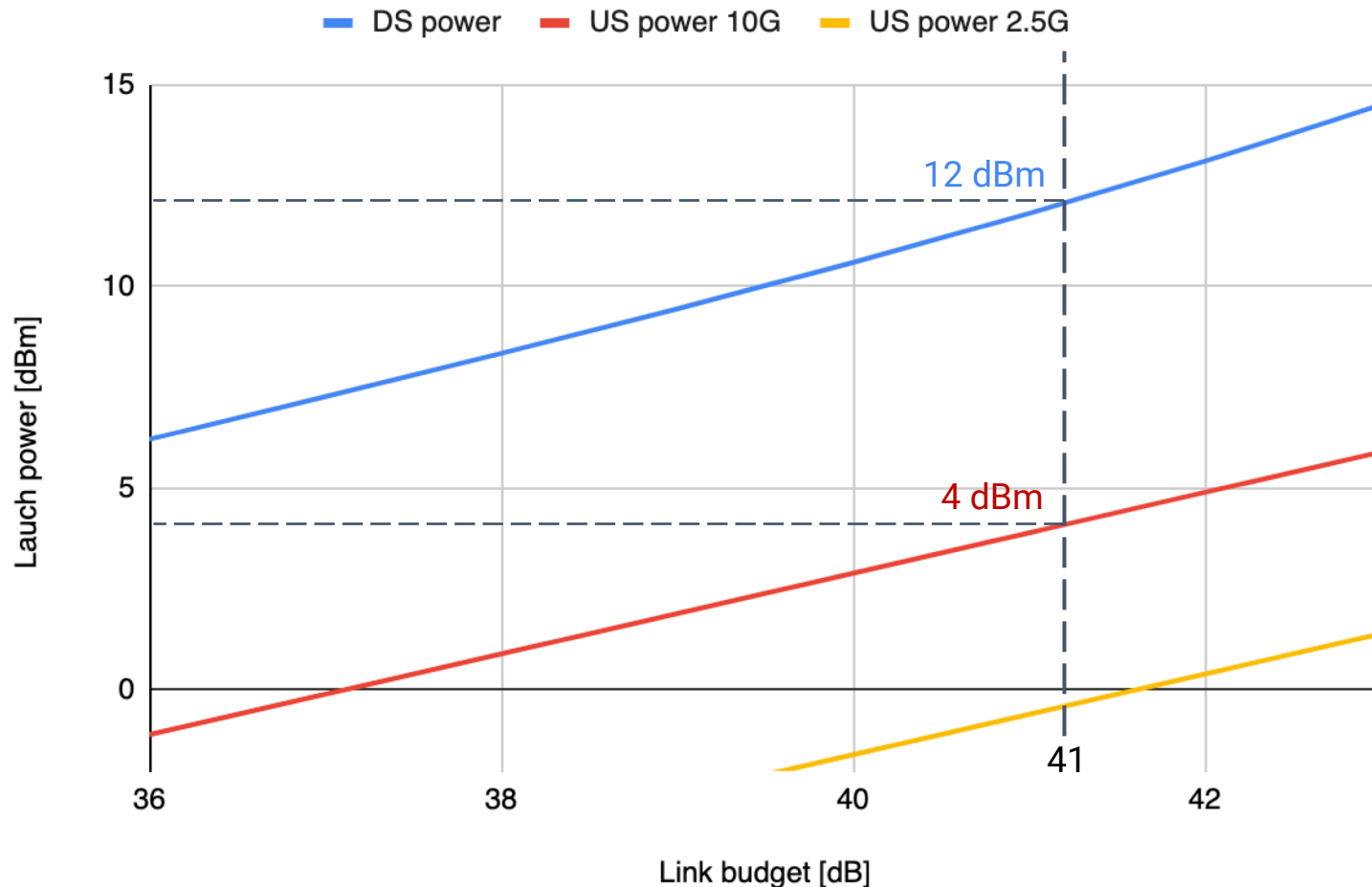


Raman penalty: DS in C; US in L



- Using the C-band for DS and L-band for US moves the higher powered DS signals to the shorter wavelength side
- This creates Raman gain for the US signals, rather than Raman power penalty
- The increase in power should not be included in the link budget as it will contain noise, since it comes from modulated signals rather than a CW pump
- Assume ***ZERO*** Raman penalty for the US signals

Required output power



- The required US and DS output power is shown in the graph
- Without Raman penalties, the required 10G US ONU launch power is 4 dBm, the same of NG-PON2
- DS power required at 12 dBm per wavelength
- It is easier to build high-power EDFAs in the C-band, rather than in the L-band

Summary

	Required Launch powers [dBm]		
	DS	US 10G	US 2.5G
DS: L - US: C	12	7.5	3
DS: C - US: L	12	4	-0.5

- Premium grade optical splitters and CAWGs were assumed to reduce the link budget required to achieve the objectives (50 km with 64-way power split)
- Operating in DS L-band and US C-band, as per NG-PON2 and this task force's previous intention, results in a large Raman penalty, requiring very high ONU launch powers to close the link budget
- Operating in DS C-band and US L-band avoids Raman penalties on the US channels, allowing the link budget to be close using similar ONU output powers to NG-PON2 specifications. Additionally, the implementation of the high-power EDFA in the DS direction is easier in the C-band

Thank you