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25G/50G/100G EPON wavelength plan comparisons

Updated version of harstead_3ca_4b_0916 per discussion in Fort Worth

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Sept. 2016

Updates per discussion in Fort Worth

1. Slide 8: Added missing information for Plan F
2. Slides 8, 11, 14: corrected error: Plans D-3 and D: upstream 25G laser is in O-band
3. Slides 8, 11, 14: Added columns: upstream throughput degradation of one 25G channel if TDM coexistence. Also added (because this is the trade-off) column to track the extra 10G optical receiver in the100G OLT if WDM coexistence and 1+3. Note that since Plan C could accommodate either WDM or TDM coexistence, it has two entries now.
4. Removed column “WBF (DS0/DS1 gap)”: decided to make the assumption in favor of Plans A and D that they will be adjusted to meet ≥10 nm if that is the requirement for lowest cost ONU WBF.
5. Then, rescored all the plans.
   - Showing new detailed scoring for all plans, separately for 1+3 and 1+4 scenarios
   - Then further evaluation only for the options selected in Fort Worth: Plans A, B, C, D. For both 10 km and 20 km.
   - New slides:

Scenario	All plans	Plans selected in Ft. Worth	Plans selected in Ft. Worth, 10 km
1+3	Slide 9	Slide 12	Slide 15
1+4	Slide 10	Slide 13	Slide 16

6. New conclusions (slide 17) based on the new results.

Straw Poll # 1

The 802.3ca standard shall specify wavelengths for 25G, 50G, and 100G systems in O-Band.

Yes:	15
No:	0
Not enough information:	9

Those voting "Not enough information" in Straw Poll #1 suggested the following information is needed to make a decision.

1) Exact (detailed) wavelength plan including support for coexistence (TDM or WDM).
2) Full cost comparison between all O-Band and other solutions.
3) More consensuses in presentations.
4) Dispersion compensation analysis of all solutions.
5) Full power budget for full 100G system (including mux losses) and what is needed to close the gap.

Wavelength Plan Inventory as of 7/27/16

	A	B	C	D	E	F	G
ds0	O	O	O	S/C/L	O	O	
ds1	O	O	S/C/L	S/C/L	S/C/L	L	
ds2	O	O	S/C/L	S/C/L	S/C/L	L	
ds3	O	O	S/C/L	S/C/L	S/C/L	L	
ds4	none	O or none	S/C/L or none	none	none	L	
us0	O	O	O	O	O	O	
us1	O	O	S/C/L	O	O	C	
us2	O	O	S/C/L	O	O	C	
us3	O	O	S/C/L	O	O	C	
us4	none	O or none	S/C/L or none	none	none	C	
author	JJ+FE+YG #1	EH #1	EH#2	JJ	DL	ED	

kramer_3ca_5_0716.pdf

Note: of the 6 plan options in contribution liu_3ca_1_0916.pdf ,only plans recommended in its Summary slide are considered

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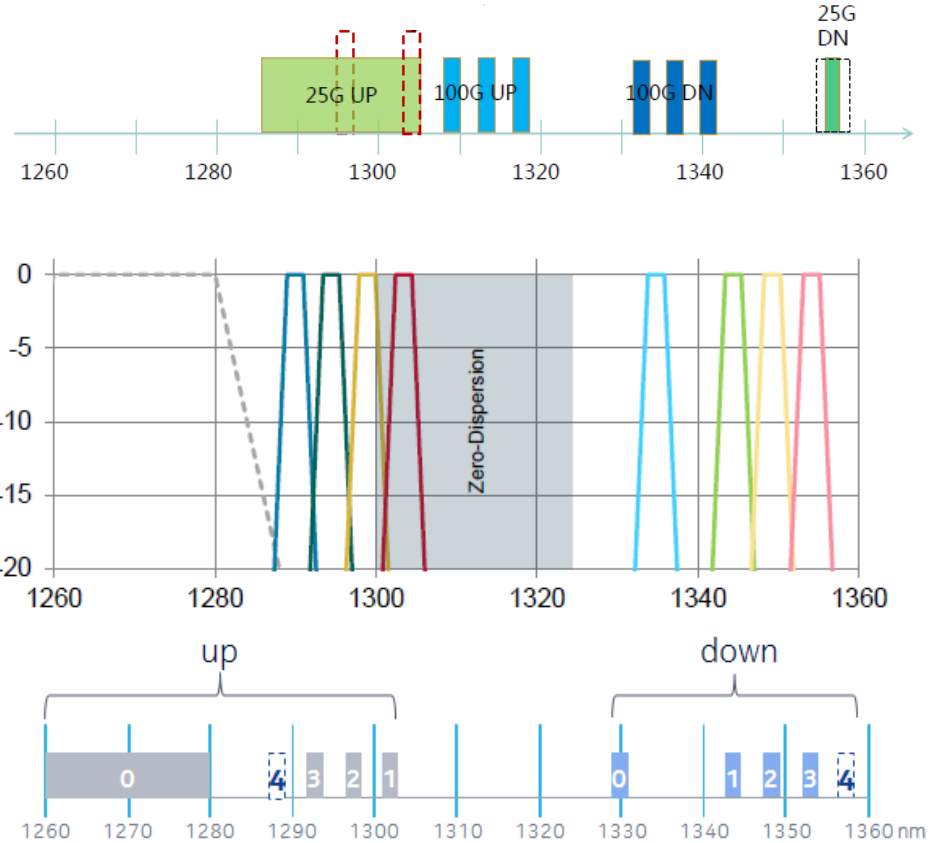
Plans A/B: All O-band

Plan A, Option 1
liu_3ca_1_0916.pdf

Plan A
johnson_3ca_1_0916.pdf

Plan B
harstead_3ca_2_0916.pdf



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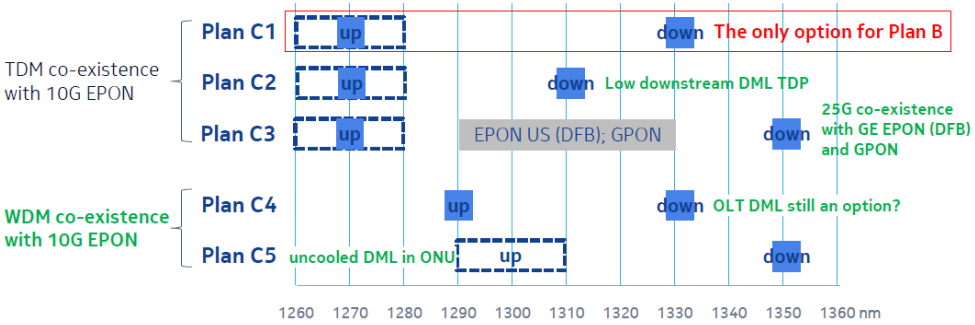
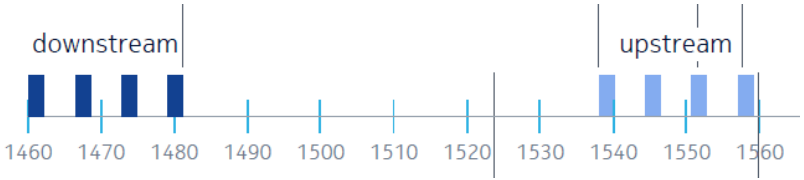
Plan C: 25G in O-band, 100G in S/C-band

Plan C
harstead_3ca_3_0916.pdf





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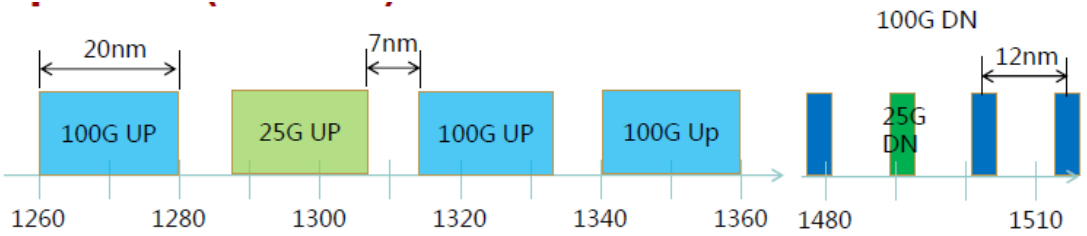
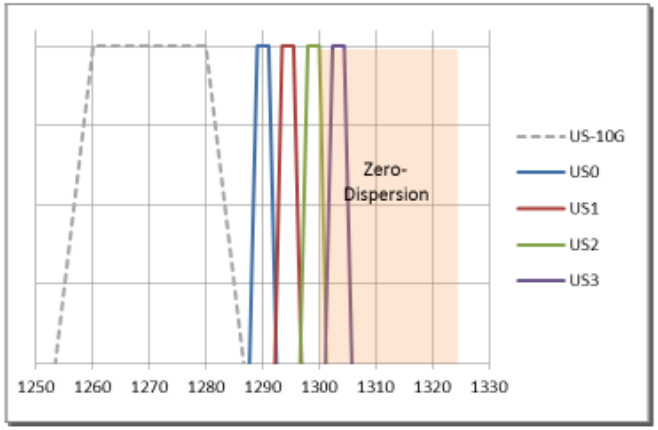
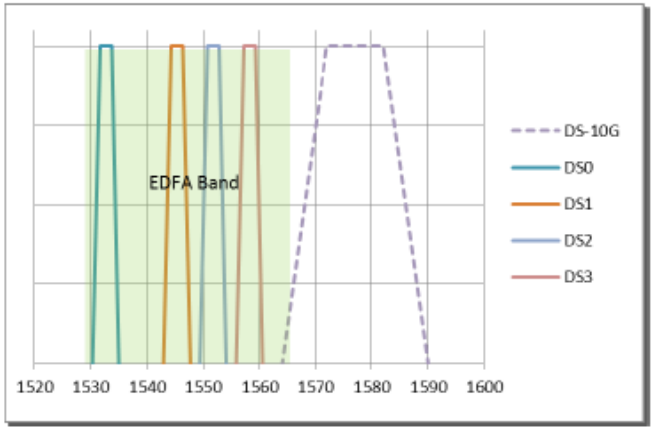
Plan D: US in O-band, DS in S/C-band

Plan D, option 3
liu_3ca_1_0916.pdf



Plan D
johnson_3ca_2_0916.pdf





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Simple comparison: all proposed plans

Simple scoring: ✓= 1; ✖= -1

Option	Bands	Co-existence w/10G EPON	One 25G through put shared w/10G	Impacts on 25G EPON			Impacts on 100G EPON					
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT includes 10G Rx	Dispersion compensation ?
Plan A, option 1	All O-band	WDM	✓no	✓✓DS&US	✓yes, uncooled DML	✓no	✓✓DS&US	no	no	no	1+3: yes ✓1+4: no	✓no
Plan A	All O-band	WDM	✓no	✓✓DS&US	no, cooled , 2 nm width	✓no	✓✓DS&US	✓yes	✓yes	no	1+3: yes ✓1+4: no	✓no
Plan B	All O-band	TDM	yes	✓✓DS&US	✓yes , uncooled DML	✓no	✓✓DS&US	1+3: no ✓1+4: yes	1+3: no ✓1+4: yes	no	✓no	✓no
Plan C, TDM	25G in O, 100G in S/C	TDM	yes	✓✓DS&US	✓yes , uncooled DML	✓no	no	✓yes	✓yes	✓US	✓no	for >10 km
Plan C, WDM	25G in O, 100G in S/C	WDM	✓no	✓✓DS&US	✓yes , uncooled DML	✓no	no	✓yes	✓yes	✓US	1+3: yes ✓1+4: no	for >10 km
Plan D, option 3	US in O, DS in S	WDM→TDM	yes	✓US	✓yes , uncooled DML	for >13 km	✓US	✓yes	no	no	✓no	for >10 km ✖? duplex TRx
Plan D	US in O, DS in C	WDM	✓no	✓US	no, cooled , 2 nm width	for >10 km	✓US	✓yes	✓yes	✓DS	1+3: yes ✓1+4: no	for >10 km ✖? duplex TRx
Plan F	25G in O, 100G in C/L	WDM	✓no	✓✓DS&US	✓yes , uncooled DML	✓no	no	✓yes	✓yes	✓✓US and DS	1+3: yes ✓1+4: no	✖? for >8 km

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Scoring, all proposed plans: 1+3

Option	Bands	Co-existence with 10G EPON	25G λ0 shared with 10G	Impacts on 25G EPON			Impacts on 100G EPON						Score
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT iIncludes 10G Rx	Dispersion compensation?	
Plan A, option 1	All O-band	WDM	1	2	1	1	2	0	0	0	0	1	8
Plan A	All O-band	WDM	1	2	0	1	2	1	1	0	0	1	9
Plan B	All O-band	TDM	0	2	1	1	2	0	0	0	1	1	8
Plan C, TDM	25G in O, 100G in S/C	TDM	0	2	1	1	0	1	1	1	1	0	8
Plan C, WDM	25G in O, 100G in S/C	WDM	1	2	1	1	0	1	1	1	0	0	8
Plan D, option 3	US in O, DS in S	WDM→TDM	0	1	1	0	1	1	0	0	1	-1	4
Plan D	US in O, DS in C	WDM	1	1	0	0	1	1	1	1	0	-1	5
Plan F	25G in O, 100G in C/L	WDM	1	2	1	1	0	1	1	2	0	-1	8

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Scoring, all proposed plans: 1+4

Option	Bands	Co-existence with 10G EPON	25G λ0 shared with 10G	Impacts on 25G EPON			Impacts on 100G EPON					Score
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT iIncludes 10G Rx	Dispersion compensation?	
Plan A, option 1	All O-band	WDM	1	2	1	1	2	0	0	0	1	1	9
Plan A	All O-band	WDM	1	2	0	1	2	1	1	0	1	1	10
Plan B	All O-band	TDM	0	2	1	1	2	1	1	0	1	1	10
Plan C, TDM	25G in O, 100G in S/C	TDM	0	2	1	1	0	1	1	1	1	0	8
Plan C, WDM	25G in O, 100G in S/C	WDM	1	2	1	1	0	1	1	1	1	0	9
Plan D, option 3	US in O, DS in S	WDM→TDM	0	1	1	0	1	1	0	0	1	-1	4
Plan D	US in O, DS in C	WDM	1	1	0	0	1	1	1	1	1	-1	6
Plan F	25G in O, 100G in C/L	WDM	1	2	1	1	0	1	1	2	1	-1	9

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Simple comparison: Plans chosen in Fort Worth

Simple scoring: ✓= 1; ✗= -1

Option	Bands	Co-existence w/10G EPON	One 25G through put shared w/10G	Impacts on 25G EPON			Impacts on 100G EPON					
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT includes 10G Rx	Dispersion compensation ?
Plan A	All O-band	WDM	✓no	✓✓DS&US	no, cooled , 2 nm width	✓no	✓✓DS&US	✓yes	✓yes	no	1+3: yes ✓1+4: no	✓no
Plan B	All O-band	TDM	yes	✓✓DS&US	✓yes , uncooled DML	✓no	✓✓DS&US	1+3: no ✓1+4: yes	1+3: no ✓1+4: yes	no	✓no	✓no
Plan C, TDM	25G in O, 100G in S/C	TDM	yes	✓✓DS&US	✓yes , uncooled DML	✓no	no	✓yes	✓yes	✓US	✓no	for >10 km
Plan C, WDM	25G in O, 100G in S/C	WDM	✓no	✓✓DS&US	✓yes , uncooled DML	✓no	no	✓yes	✓yes	✓US	1+3: yes ✓1+4: no	for >10 km
Plan D	US in O, DS in C	WDM	✓no	✓US	no, cooled , 2 nm width	for >10 km	✓US	✓yes	✓yes	✓DS	1+3: yes ✓1+4: no	for >10 km ✗? duplex TRx

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Scoring, Plans chosen in Fort Worth: 1+3

Option	Bands	Co-existence with 10G EPON	25G λ0 shared with 10G	Impacts on 25G EPON			Impacts on 100G EPON						Score
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT iIncludes 10G Rx	Dispersion compensation?	
Plan A	All O-band	WDM	1	2	0	1	2	1	1	0	0	1	9
Plan B	All O-band	TDM	0	2	1	1	2	0	0	0	1	1	8
Plan C, TDM	25G in O, 100G in S/C	TDM	0	2	1	1	0	1	1	1	1	0	8
Plan C, WDM	25G in O, 100G in S/C	WDM	1	2	1	1	0	1	1	1	0	0	8
Plan D	US in O, DS in C	WDM	1	1	0	0	1	1	1	1	0	-1	5

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Scoring, Plans chosen in Fort Worth: 1+4

Option	Bands	Co-existence with 10G EPON	25G λ0 shared with 10G	Impacts on 25G EPON			Impacts on 100G EPON						Score
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT iIncludes 10G Rx	Dispersion compensation?	
Plan A	All O-band	WDM	1	2	0	1	2	1	1	0	1	1	10
Plan B	All O-band	TDM	0	2	1	1	2	1	1	0	1	1	10
Plan C, TDM	25G in O, 100G in S/C	TDM	0	2	1	1	0	1	1	1	1	0	8
Plan C, WDM	25G in O, 100G in S/C	WDM	1	2	1	1	0	1	1	1	1	0	9
Plan D	US in O, DS in C	WDM	1	1	0	0	1	1	1	1	1	-1	6

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Simple comparison: Plans chosen in Fort Worth, 10 km reach

Simple scoring: ✓= 1; ✗= -1

Option	Bands	Co-existence w/10G EPON	One 25G through put shared w/10G	Impacts on 25G EPON			Impacts on 100G EPON					
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT includes 10G Rx	Dispersion compensation ?
Plan A	All O-band	WDM	✓no	✓✓DS&US	no, cooled , 2 nm width	✓no	✓✓DS&US	✓yes	✓yes	no	1+3: yes ✓1+4: no	✓no
Plan B	All O-band	TDM	yes	✓✓DS&US	✓yes , uncooled DML	✓no	✓✓DS&US	1+3: no ✓1+4: yes	1+3: no ✓1+4: yes	no	✓no	✓no
Plan C, TDM	25G in O, 100G in S/C	TDM	yes	✓✓DS&US	✓yes , uncooled DML	✓no	no	✓yes	✓yes	✓US	✓no	✓no
Plan C, WDM	25G in O, 100G in S/C	WDM	✓no	✓✓DS&US	✓yes , uncooled DML	✓no	no	✓yes	✓yes	✓US	1+3: yes ✓1+4: no	✓no
Plan D	US in O, DS in C	WDM	✓no	✓US	no, cooled , 2 nm width	✓no	✓US	✓yes	✓yes	✓DS	1+3: yes ✓1+4: no	✓no

Scoring, Plans chosen in Fort Worth: 1+3, 10 km

Option	Bands	Co-existence with 10G EPON	25G λ0 shared with 10G	Impacts on 25G EPON			Impacts on 100G EPON						Score
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT iIncludes 10G Rx	Dispersion compensation?	
Plan A	All O-band	WDM	1	2	0	1	2	1	1	0	0	1	9
Plan B	All O-band	TDM	0	2	1	1	2	0	0	0	1	1	8
Plan C, TDM	25G in O, 100G in S/C	TDM	0	2	1	1	0	1	1	1	1	1	9
Plan C, WDM	25G in O, 100G in S/C	WDM	1	2	1	1	0	1	1	1	0	1	9
Plan D	US in O, DS in C	WDM	1	1	0	1	1	1	1	1	0	1	8

Scoring, Plans chosen in Fort Worth: 1+4, 10 km

Option	Bands	Co-existence with 10G EPON	25G λ0 shared with 10G	Impacts on 25G EPON			Impacts on 100G EPON						Score
				Leverage DC O-band laser tech.	Low cost ONU laser	Dispersion compensation?	Leverages DC O-band laser tech	Filters: uniform CS and width	SOA: narrow passband, spectrum	EDFA option	OLT iIncludes 10G Rx	Dispersion compensation?	
Plan A	All O-band	WDM	1	2	0	1	2	1	1	0	1	1	10
Plan B	All O-band	TDM	0	2	1	1	2	1	1	0	1	1	10
Plan C, TDM	25G in O, 100G in S/C	TDM	0	2	1	1	0	1	1	1	1	1	9
Plan C, WDM	25G in O, 100G in S/C	WDM	1	2	1	1	0	1	1	1	1	1	10
Plan D	US in O, DS in C	WDM	1	1	0	1	1	1	1	1	1	1	9

Conclusions: Simple comparison of plans selected in Fort Worth

Taking in account margin of error (due to the crudeness of the scoring in this simple comparison), these are the plans that appear to be optimize costs across both 25G and 100G EPON:

20 km	10 km
A, B, C	A, B, C, D

Next steps:

1. Inputs identified in harstead_3ca_5_0916 will enable refinement of this comparison
2. Weighting the criteria should also improve the accuracy of the comparison.
3. This document will be iterated accordingly


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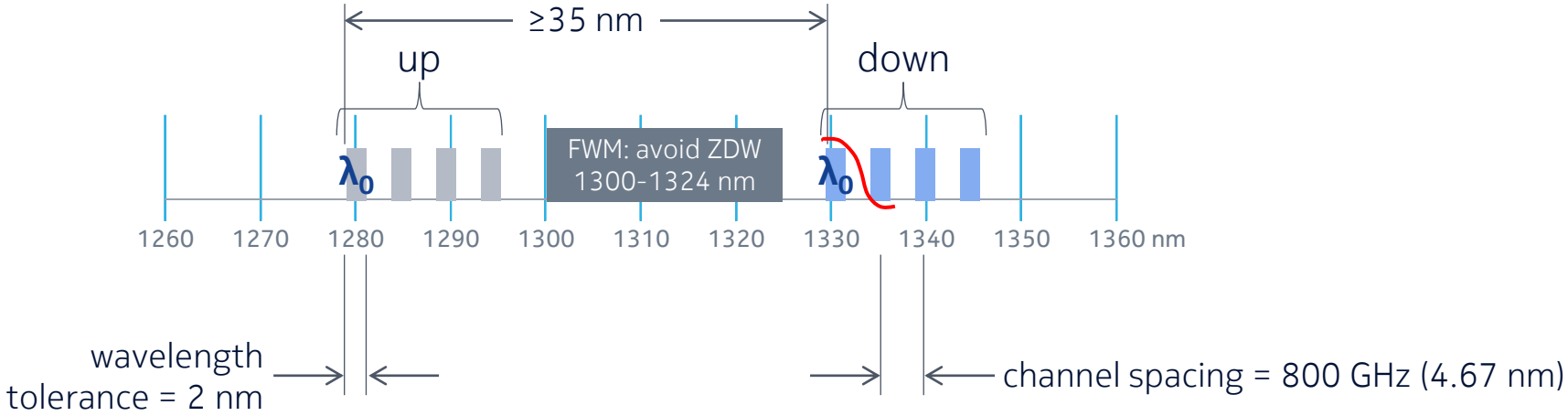
backup

Plan based exclusively on 800 GHz CS



However, optical vendor input indicates potential cost impacts

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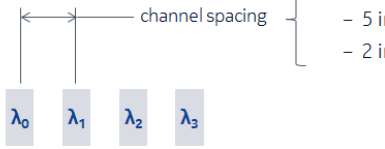
Cost view on channel spacing and wavelength tolerance

From harstead_3ca_1_0716:

Transmitter wavelength and wavelength tolerance: responses

What is the minimum channel spacing and minimum wavelength tolerance that can be supported without imposing significant additional cost?



Vendors split:

- 5 indicated 800 GHz (4.5 nm)
- 2 indicated wider spacings, 6 and 10 nm.

	number	mean	σ
EML	4	3.4	1.4
cooled DML	6	3.0	1.2

→**Inputs to be used in harstead_3ca_3_0716**

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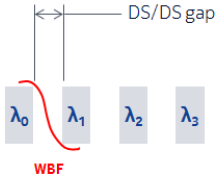
ONU receiver wavelength blocking filter (WBF) cost and insertion loss: responses



1. What is the minimum size of the downstream/downstream gap before the WBF imposes significant cost and insertion loss?

	number	mean	σ
Min value (nm)	4	11	7

2. What is the cost adder and insertion loss if the gap is about 3 nm (800 GHz LAN WDM)?
   - 5 responses, **4: high, 1: small**

→**Inputs to be used in harstead_3ca_3_0716**

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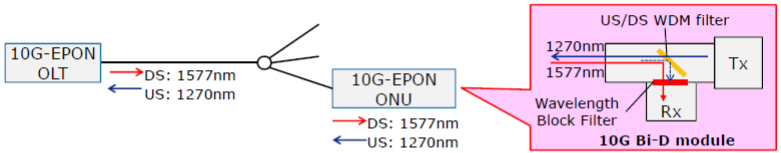
DS/US guard band to avoid collimation cost

funada_3ca_1_0316

Wavelength allocation
-US/DS gap, Rx guard band -

- Existing access network and ONU Bi-D module structure.



- Large part of system cost comes from ONU, keep familiar and economical Bi-D structure for NG-EPON ONU as far as possible.

Light coupling scheme of Bi-D	US/DS Gap	Rx guar band
Non-collimated light	>35nm	>10nm
Collimated light	>20nm	>5nm

This brings us efficient wavelength usage

liu_3ca_2_0516

	DS/US	PD guard band
Focus beam	40nm	10nm
Collimated beam	20nm	5nm

Cost comparison

		Delta Size	Cost
10/10G EPON ONU module (note 1)	Focus beam	-	X
	Collimated beam	Length : ~6mm more Width: ~ 1mm more	1.3X(note 1)

Note: The delta cost (absolute value)of collimated beam structure is roundly same for 10G and 25G (bit rate independent). The cost difference ratio in 25G depends on the cost of 25G optics.