

TDM vs. WDM co-existence with 10G EPON: update

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Updates to harstead_3ca_2a_1116

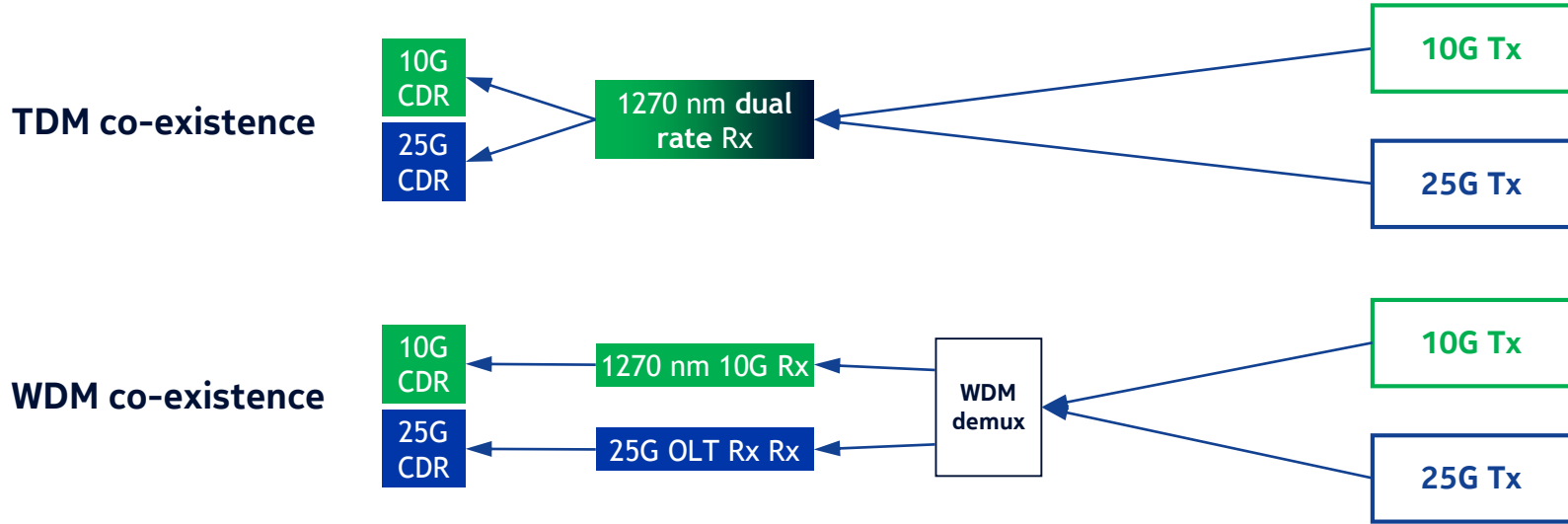
- Added slides 8 and 9
- Changed first conclusion on slide 20 accordingly.

Outline

- Comparison criteria
 1. TDM co-existence: 10G/25G sharing of upstream channel of first wavelength pair
 2. Cost of ONU laser
 3. Cost of OLT module
- Which wavelength plans support TDM and WDM co-existence with 10G EPON

10G/25G sharing of upstream channel of first wavelength pair

TDM and WDM co-existence



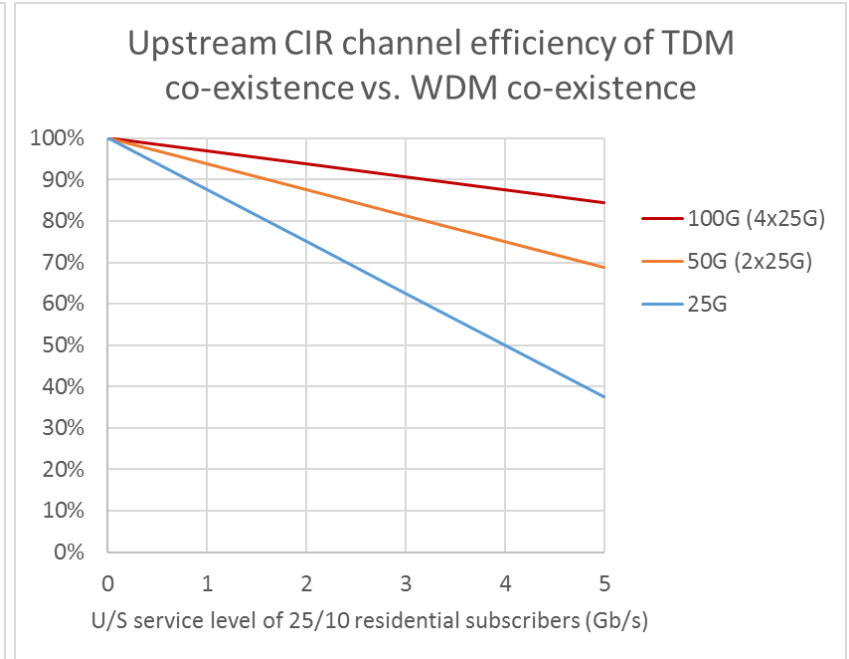
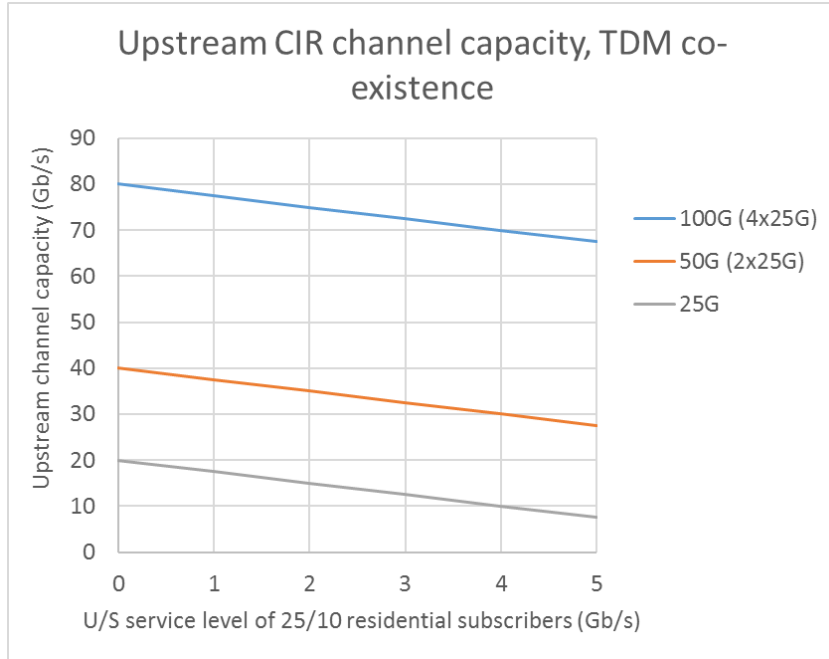
Assumptions

- The upstream 25G channel supports 20 Gb/s of real L2 capacity (the actual value is variable depending on traffic conditions, and can be lower)
- For the same content, a 10 Gb/s upstream burst requires $25 \div 10 = 2.5x$ more time than a 25 Gb/s upstream burst.

Use case: business users with symmetric ONUs and residential users with 25/10 ONUs on the same PON

- TDM co-existence: 10G and 25G upstream ONUs on the same PON
- Business users have 25/25, 50/50, or 100/100 ONUs and are offered service level agreements (SLAs) with committed information rate (CIR)
- Residential users have 25/10 ONUs.
- Residential U/S traffic is small
 - ~200 kb/s average/subscriber during peak hour. This is negligible in the context of 10G and 25G upstream on a PON.
 - Even if every ONU simultaneously engages in an [HD video call @1.5 Mb/s](#), this is negligible. Residential applications don't generate significant sustained upstream throughput.
- But sometimes there will be large bursts during very large file uploads and especially during speed tests. This is what has to be accommodated.
 - Assume the PON is not engineered to support multiple simultaneous speed tests.
- What is impact on business subscribers' upstream channel capacity compared to WDM co-existence? See chart next slide.
 - Example, if 1 Gb/s U/S service level is offered to residential users, 2.5 Gb/s must be reserved, or 12.5% of λ_0 U/S capacity.

Use case: TDM vs. WDM co-existence upstream capacity



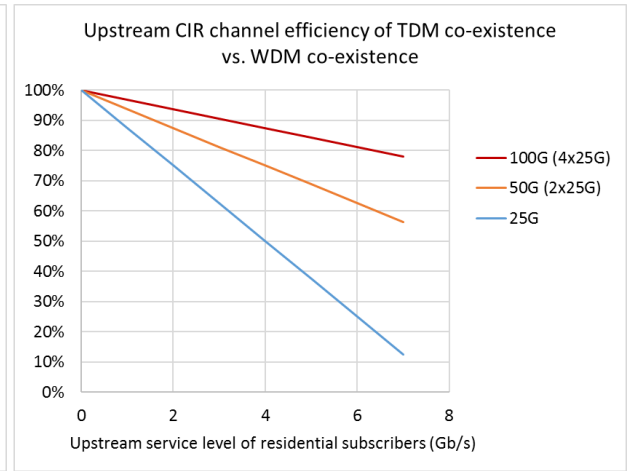
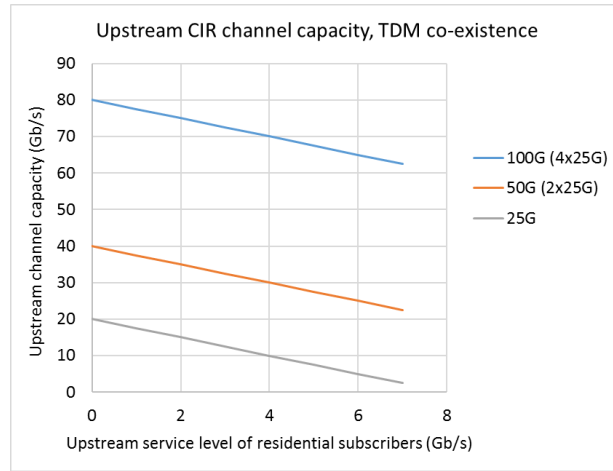
- For 1 Gb/s upstream service levels offered to 25/10 residential subscribers, minimal impact on business subscribers.
- For 5 Gb/s upstream service levels offered to 25/10 residential subscribers, minimal impact on 100G business subscribers, but ~60% impact on available CIR for 25G business subscribers

Use case: TDM vs. WDM co-existence upstream capacity: 1 Gb/s upstream ONUs

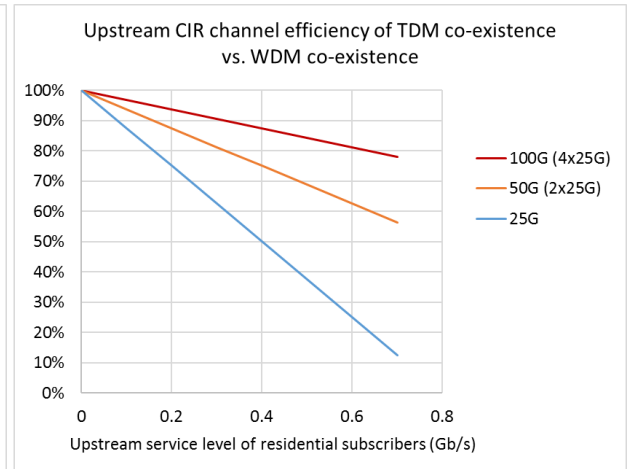
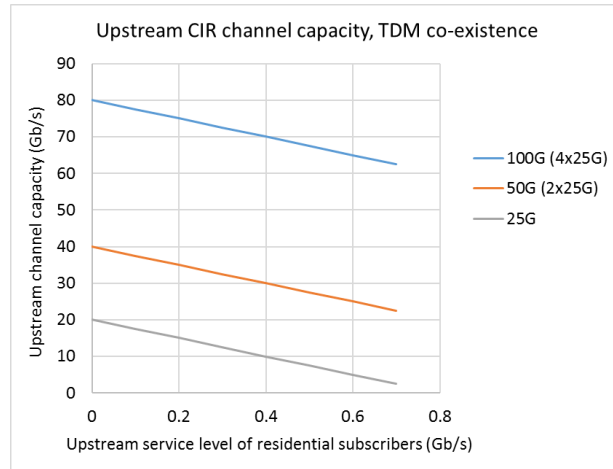
- Per discussion in San Antonio, CTC indicated that they might require 25/50/100G EPON ONUs to co-exist with 10/1 EPON ONUs, where the upstream 1 Gb/s channel is constrained to 1260-1280 nm.
- In this case, TDM co-existence would require sharing the first 25G upstream channel with 10/1 ONUs
- The analysis on the previous slides is repeated for this case. See next slide.
- The results look the same because the upstream service levels that can be offered to subscribers is proportional to their upstream ONU bandwidth.
- When 25/50/100G EPON ONUs co-exist with 10/10 and 10/1 ONUs, then a triple rate 1/10/25G OLT receiver will be required
 - 1/10G dual rate OLT receivers are commercially available today.
 - A 1/10/25G triple rate receiver will be more complex, but it's not clear that there is new and important technical problem to be solved. For further study.

TDM co-existence upstream capacity

TDM co-existence with 10 Gb/s upstream



TDM co-existence with 1 Gb/s upstream



Cost of ONU laser

Cost premium for cooled DML vs. uncooled DML in 25G ONU

- TDM co-existence will allow for an uncooled laser in the ONU (1260-1280 nm is available), while WDM co-existence (except Plan C5) will not have enough spectrum for an uncooled laser in the ONU
- A cooled 25G DML TOSA will cost 75% more than an uncooled 25G DML TOSA
- In a 25/25 ONU BOSA, the 25G transmitter will represent the large majority of the cost. Let's assume 50% higher cost for cooled DML ONU BOSA
- A 25G uncooled DML will work with PR20 loss budget. A 25G uncooled DML may require some technology improvements to work for PR30 (next slide).

TOSA	Relative cost (2020)
10G EML	1
25G uncooled DML	0.8
25G cooled DML	1.4
25G EML	1.8

Source: [harstead_3ca_1a_0716.pdf](#)

Feasibility of 25G uncooled DML for PR30 upstream loss budget

If 2 dB TDP (tanaka_3ca_1_1116) and no FEC improvement (upstream), technology improvements will need 1 more dB than indicated by [harstead_3ca_2a_0716.pdf](#)

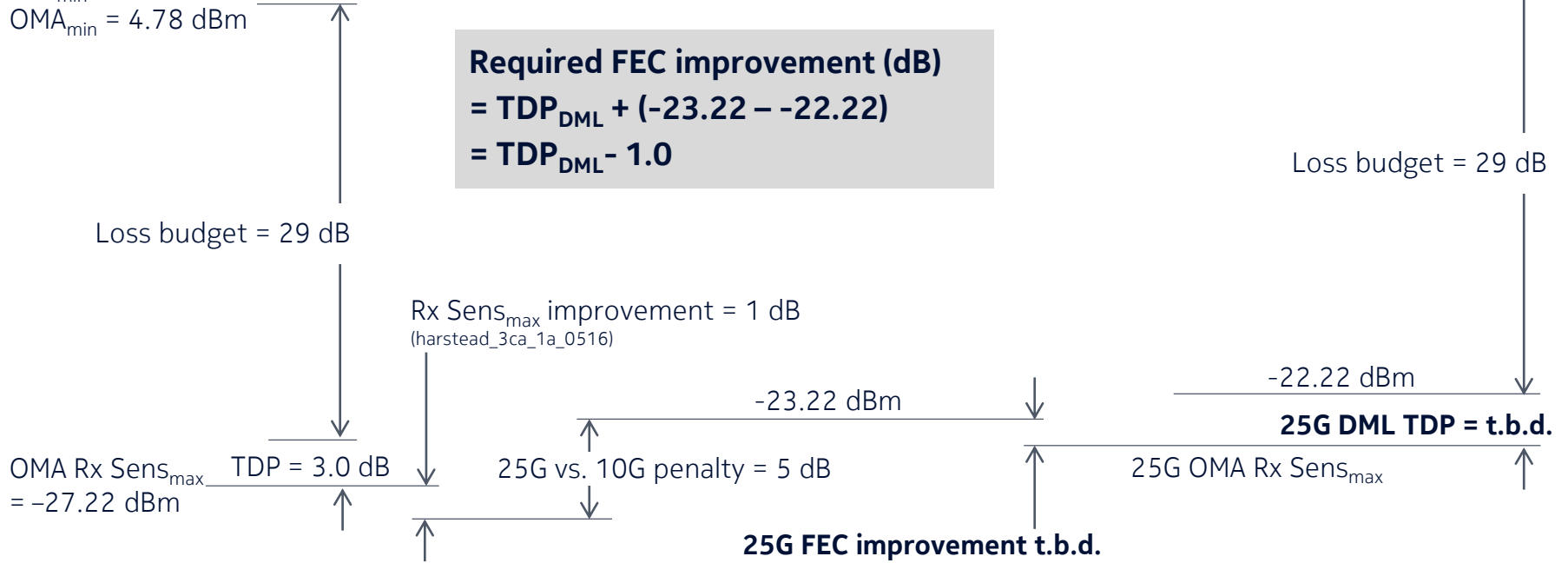
PR30 25G: uncooled DML

PR30 10G (DML)

AVP_{min} = 4 dBm, ER=6
 OMA_{min} = 4.78 dBm

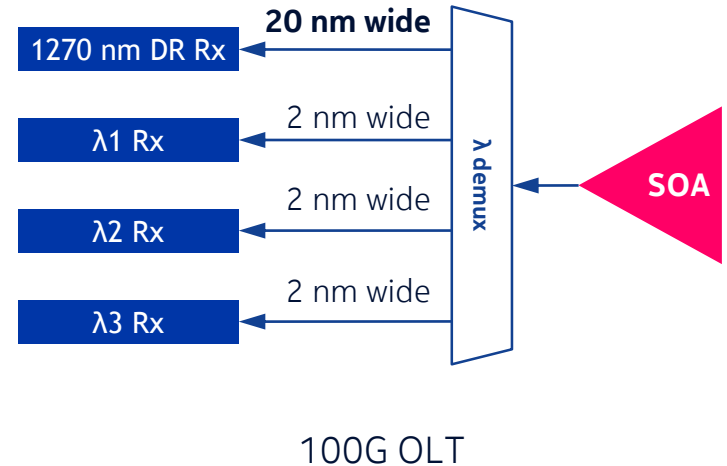
AVP_{min} = 6 dBm, ER = 6 dB
 → OMA_{min} = 6.78 dBm

Required FEC improvement (dB)
 = TDP_{DML} + (-23.22 - -22.22)
 = TDP_{DML} - 1.0



Impact of uncooled DML on OLT receiver sensitivity (applies to 1+3 only)

- If TDM co-existence is chosen to allow a low cost uncooled DML in the ONU, a 20 nm wide filter (1260-1280 nm) will be required in front of the 100G OLT λ_0 receiver.
- $\lambda_1, \lambda_2, \lambda_3$ are assumed to be on the 800 GHz grid with ~ 2 nm channel width.
- In the 100G OLT, PR30 loss budget, it is assumed an optical preamp will be required
- If it is an SOA, then the SOA spontaneous-spontaneous beat noise will be ~ 10 x higher for λ_0 compared to $\lambda_1, \lambda_2, \lambda_3$.
- This will have an effect on λ_0 receiver sensitivity.
- How much is t.b.d. ([liu_3ca_3_1116](#) is pessimistic)
- If this penalty can be overcome, then there is no issue. Otherwise it becomes problematic for 1+3 TDM co-existence.



Cost of OLT module

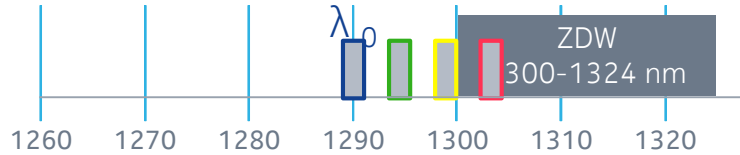
Reference: [harstead_3ca_1b_0916.pdf](#)

WDM co-existence: 100G OLT demux relaxation for all O-band upstream plans

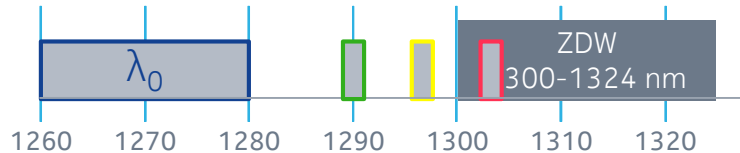
Example: Plan A

[johnson_3ca_1a_0916.pdf](#)

Plan A (TDM CE)



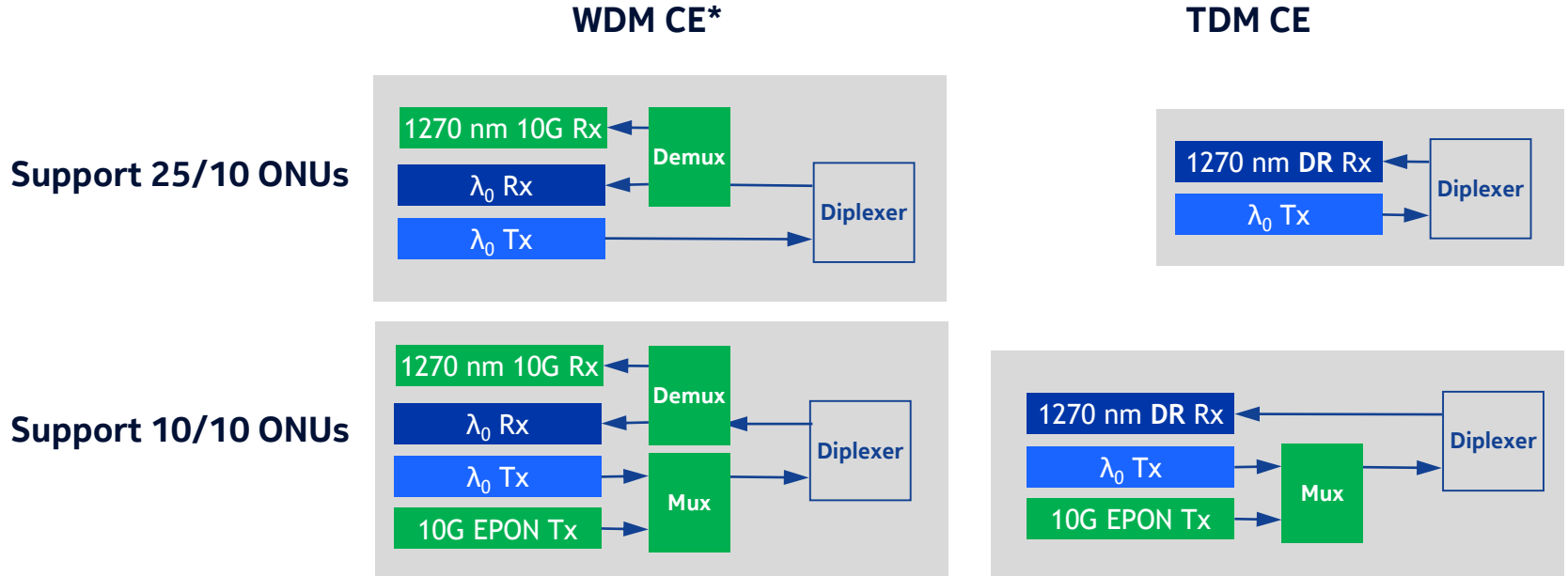
Plan A-
WDM CE version



- Relaxed spacing between wavelengths
- Less FWM risk?

Also applies to Plans B and D.

25G OLT optical module architecture: WDM and TDM co-existence with 10G EPON

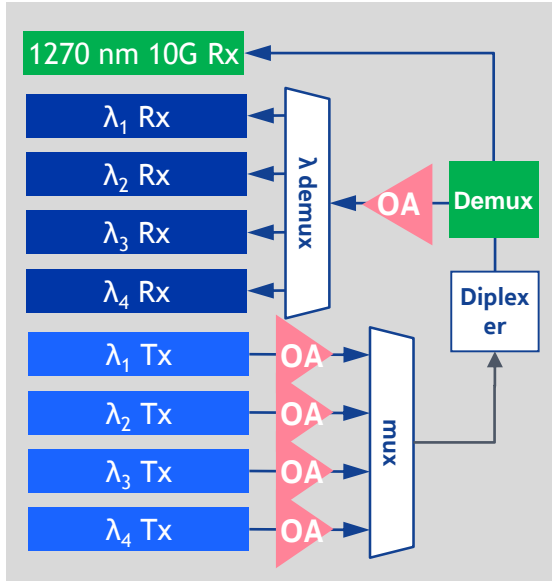


Reference: [harstead_3ca_1b_0916.pdf](#)

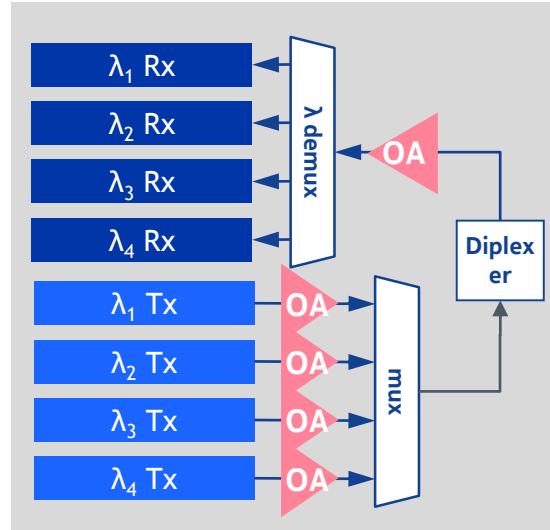
*in 25G and 100G OLTs, it would be possible to implement a dual-rate receiver in the case of WDM co-existence (combining upstream 10G @1270 nm + 25G λ_0). But this would require sharp filtering between λ_0 and λ_1 in the 100G demux, and brings back the disadvantage of sharing upstream capacity between 10G and 25G.

100G OLT optical module architecture, supporting 25/10 ONUs

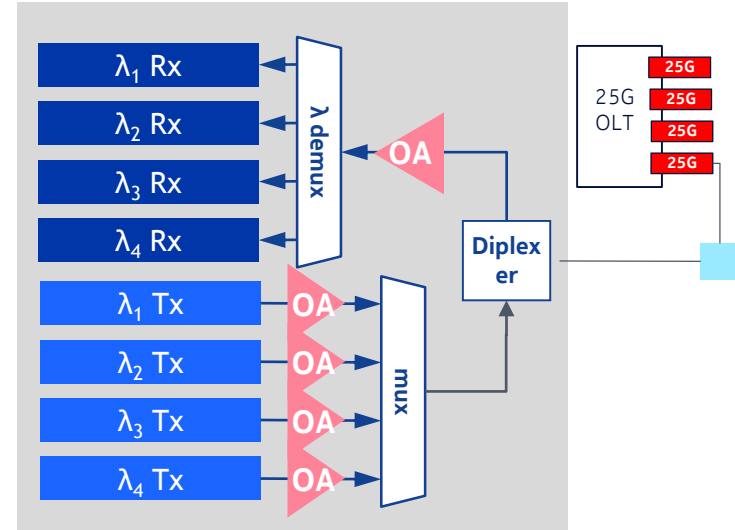
1+3, WDM CE



1+3, TDM CE



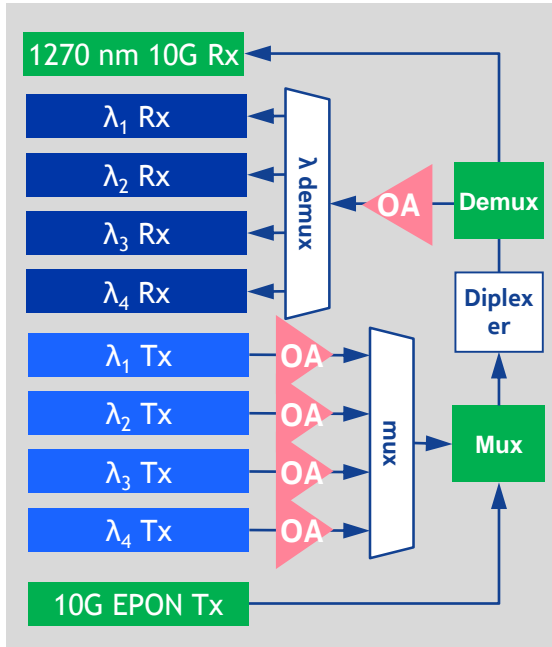
1+4, WDM or TDM CE



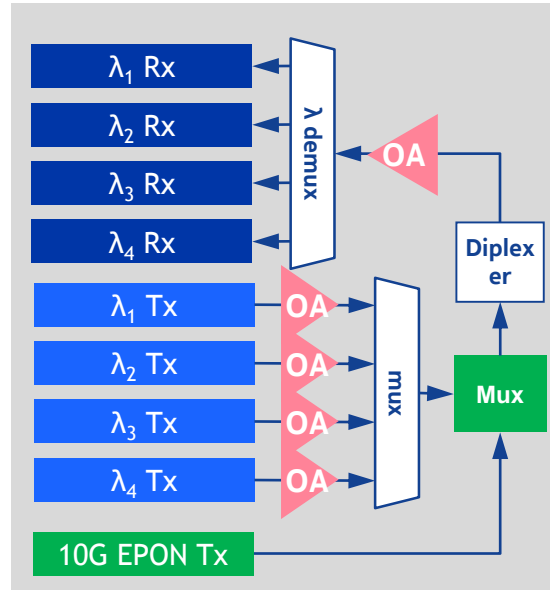
Reference: [harstead_3ca_1b_0916.pdf](#)

100G OLT optical module architecture, supporting 25/10 and 10G EPON ONUs

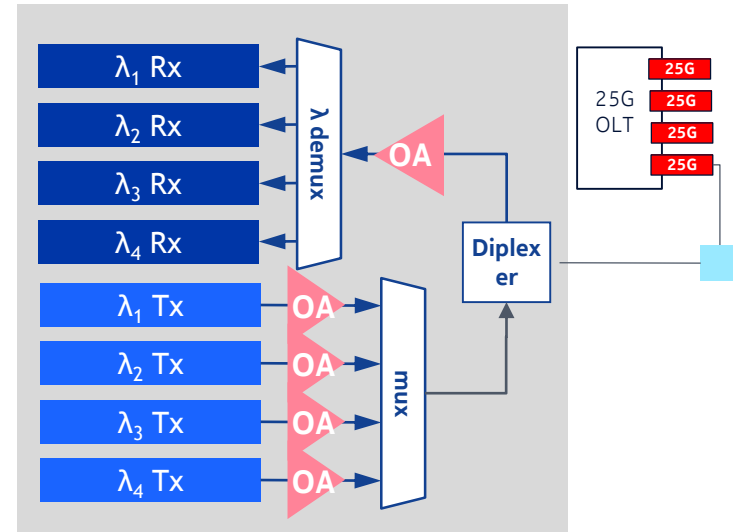
1+3, WDM CE



1+3, TDM CE



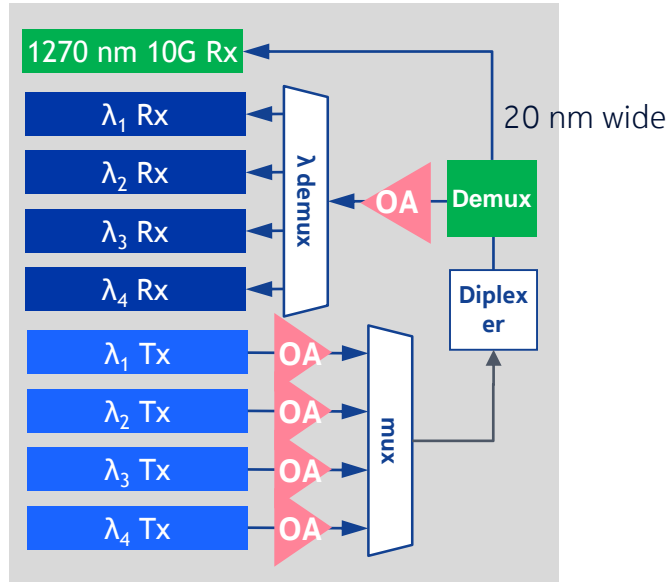
1+4, WDM or TDM CE



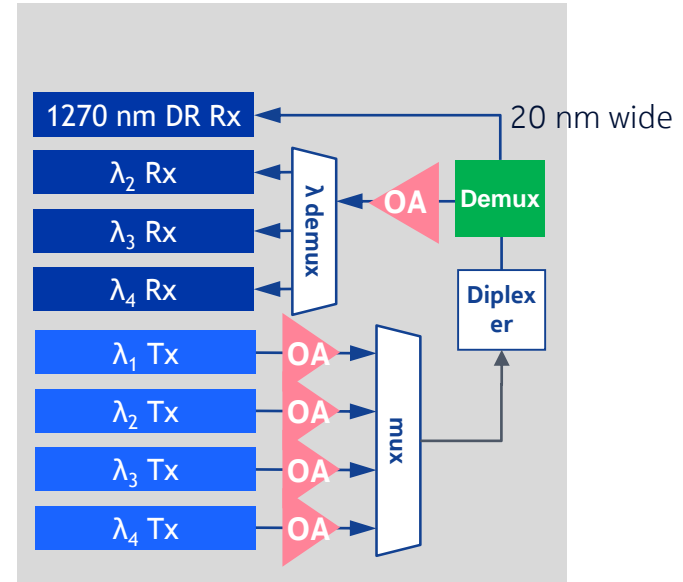
Reference: [harstead_3ca_1b_0916.pdf](#)

Upstream filtering architecture (1+3 only)

1+3, WDM co-existence



1+3, TDM co-existence



- In the 1+3 case, 100G OLTs have virtually the same upstream filtering architectures whether TDM or WDM co-existence. Both have to support a 20 nm filter.

Conclusions

- TDM co-existence: sharing of upstream channel of first wavelength pair with lower speed ONUs
 - If multi-gigabit service levels are offered to 25/10 ONUs (or multi-100M service levels to 10/1 ONUs) then a significant impact on the CIR that could be provisioned to 25/25 ONUs results.
 - Otherwise,
 - for lower service levels: e.g. 1 Gb/s to 25/10 ONUs (or 100M to 10/1 ONUs), or for
 - CIR on 50/50 or 100/100 ONUs,the upstream channel capacity is not greatly affected.
- Cost of ONU laser.
 - TDM co-existence allows for the possibility of an uncooled laser in the 25/25 ONU: perhaps the biggest single cost savings for 25G PON.
 - An uncooled laser should be usable for the PR20 loss budget; for PR30 it is t.b.d.
 - On the other hand, in the pre-amplified 1+3 100G OLT architecture, spontaneous-spontaneous beat noise will be larger for 20 nm of bandwidth.
- OLT optical module
 - WDM co-existence will add additional components (optical demux, optical receiver) impacting size and cost of the 25G OLT and 50/100G OLT (if 1+3 architecture) optical modules.
 - WDM co-existence will require tighter demux specifications
 - TDM co-existence will require dual rate receiver, but will probably not add significant size or cost

Wavelength plan summary

Plan	10G EPON co-existence
A	WDM
B	TDM
C1, C2, C3	TDM
C4, C5	WDM
D	WDM

NOKIA