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Towards building a low cost 25G "base PHY" for 100G EPON

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Jan. 2016

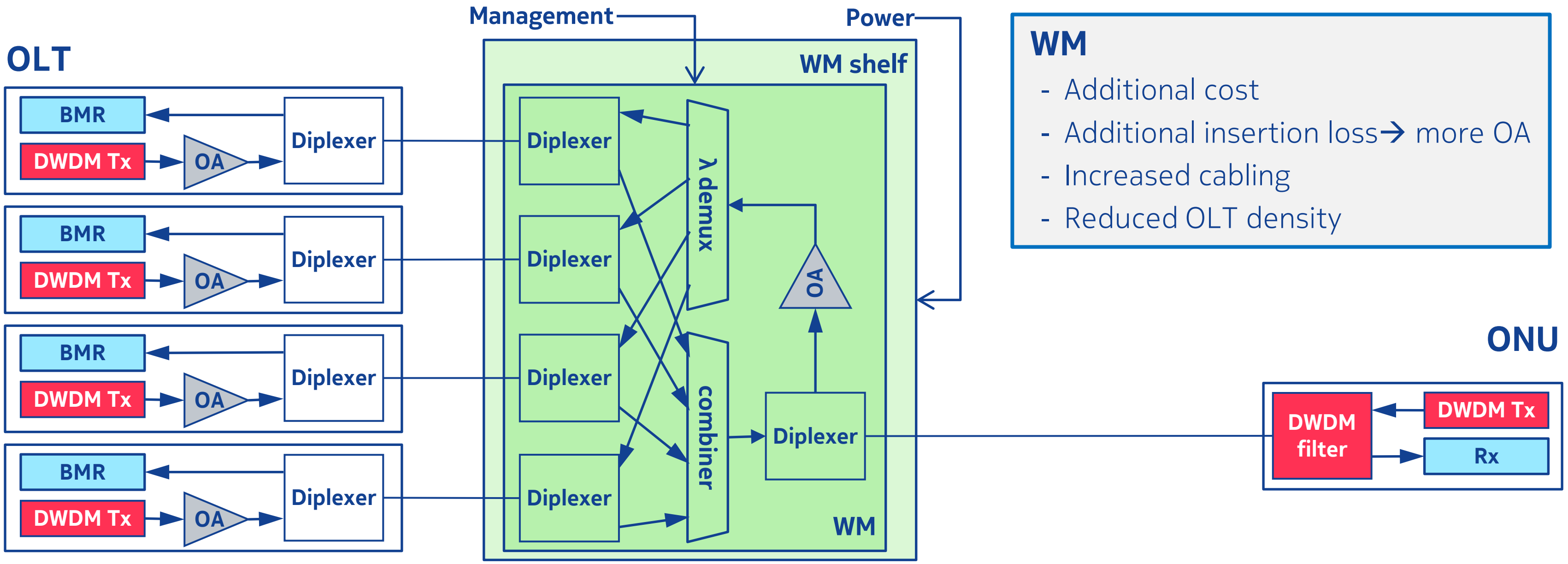
Low cost 25G “base PHY” for 100G EPON

- Target: 25G base PHY as a low cost 1st wavelength pair
  - of an extensible 4x25G 100G EPON
- Can be realized by design choices that defer cost and complexity to the 2nd wavelength pair.
- The goal is a lower cost per bit than 10G EPON
  - i.e. 2.5x more bandwidth for <2.5x increase in cost
- And a faster time to market
- Especially for 25/10 asymmetric

There are consequences of putting PON wavelengths onto a DWDM grid

DWDM Tx in OLT and ONU

- Additional cost for 100 GHz CS vs. sloppy 5/20 nm width
- Burst mode (BM) wavelength excursions lead to upstream crosstalk



WM

- Additional cost
- Additional insertion loss→ more OA
- Increased cabling
- Reduced OLT density

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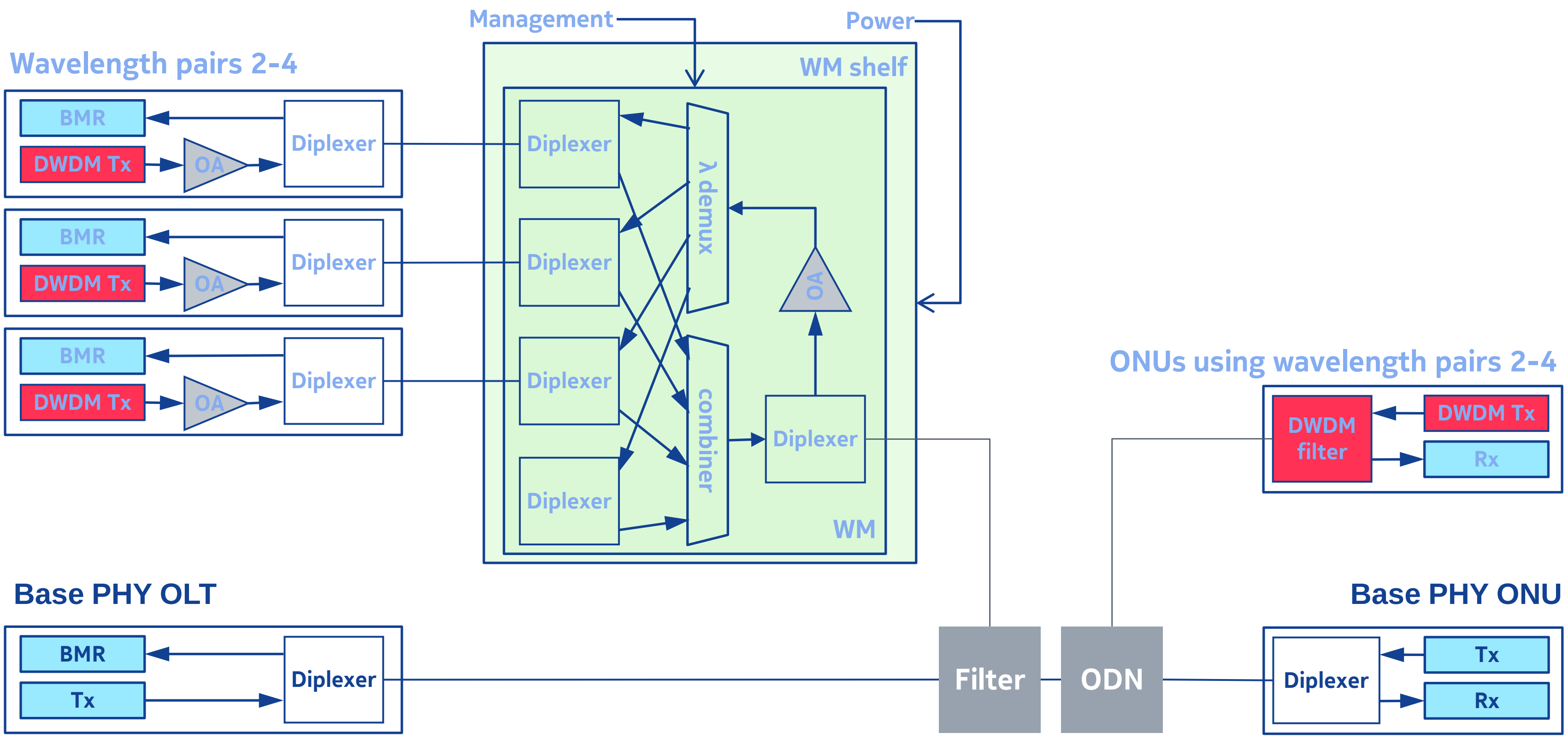
Step 1 Defer DWDM until the 2nd wavelength pair



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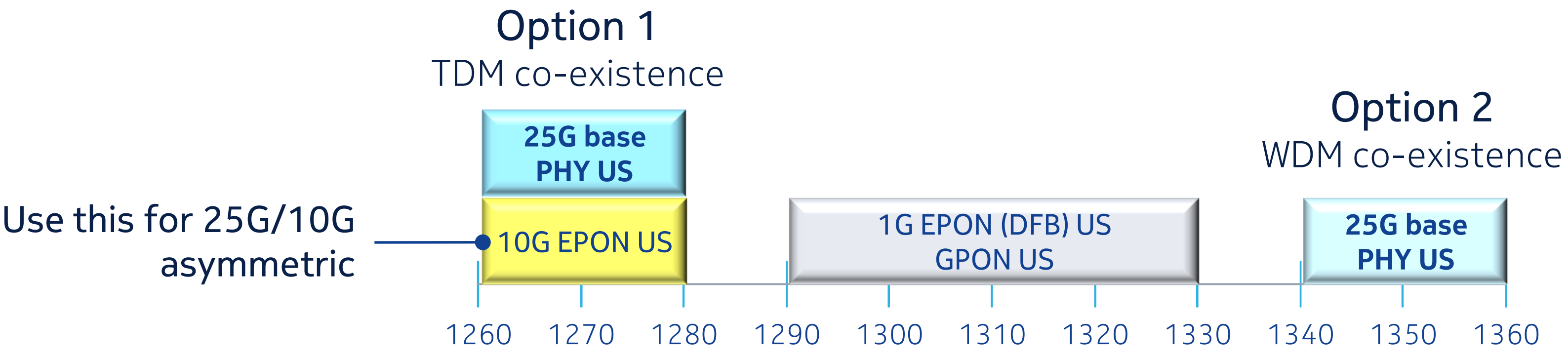
Step 2 Choose O-band for base PHY upstream

- Allows for ONU DML. Vs. EML,
  - DML is lower cost
  - DML has slightly higher output power.
- Dispersion compensation can be avoided even for DML.

Two options for co-existence with 10/10 EPON:



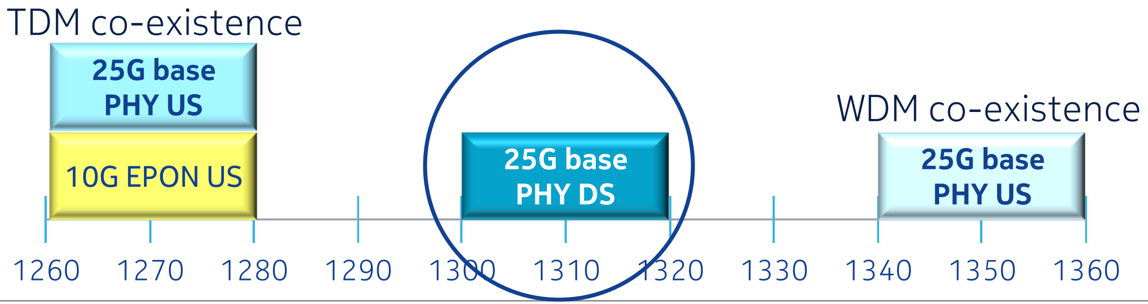
Step 3 Choose O-band for base PHY downstream

- For the same reasons as base PHY upstream

Two options:

- **Option 1**
  - Supports 10G EPON TDM coexistence
  - Supports 1G EPON (DFB) and GPON coexistence

- **Option 2**
  - Supports 10G EPON TDM or WDM coexistence
  - 25G transmitter λ is identical to 100G Ethernet



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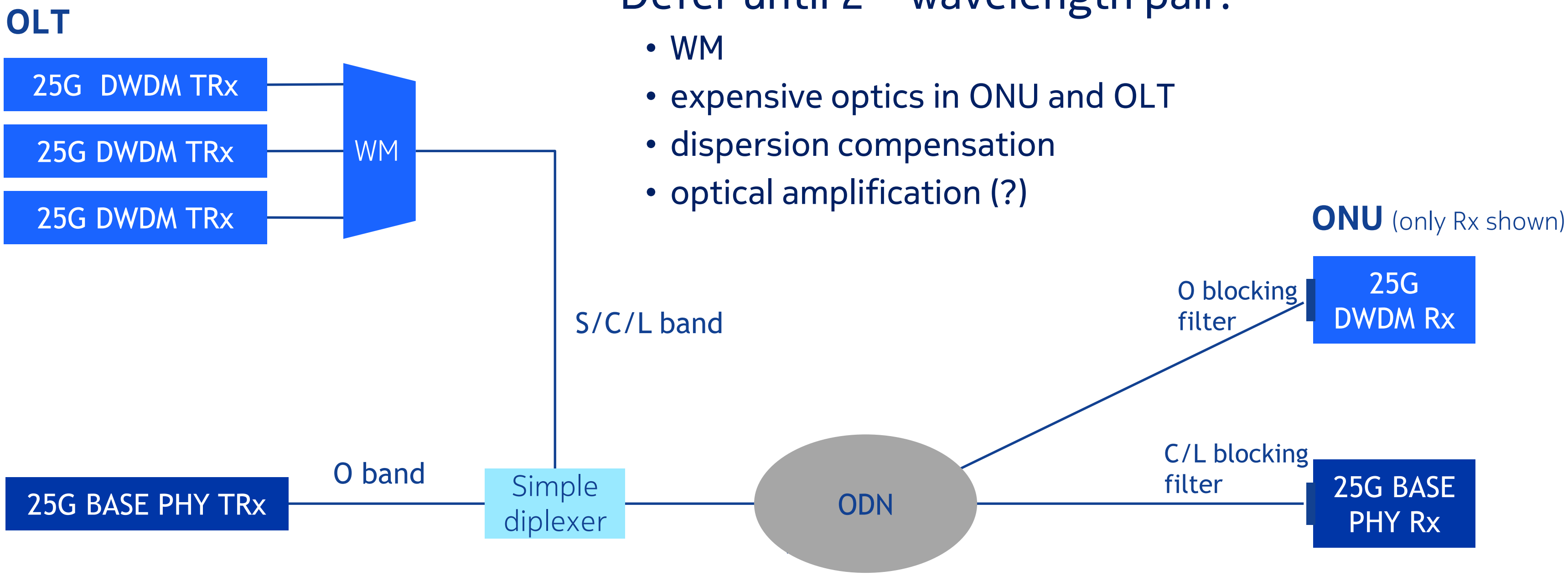
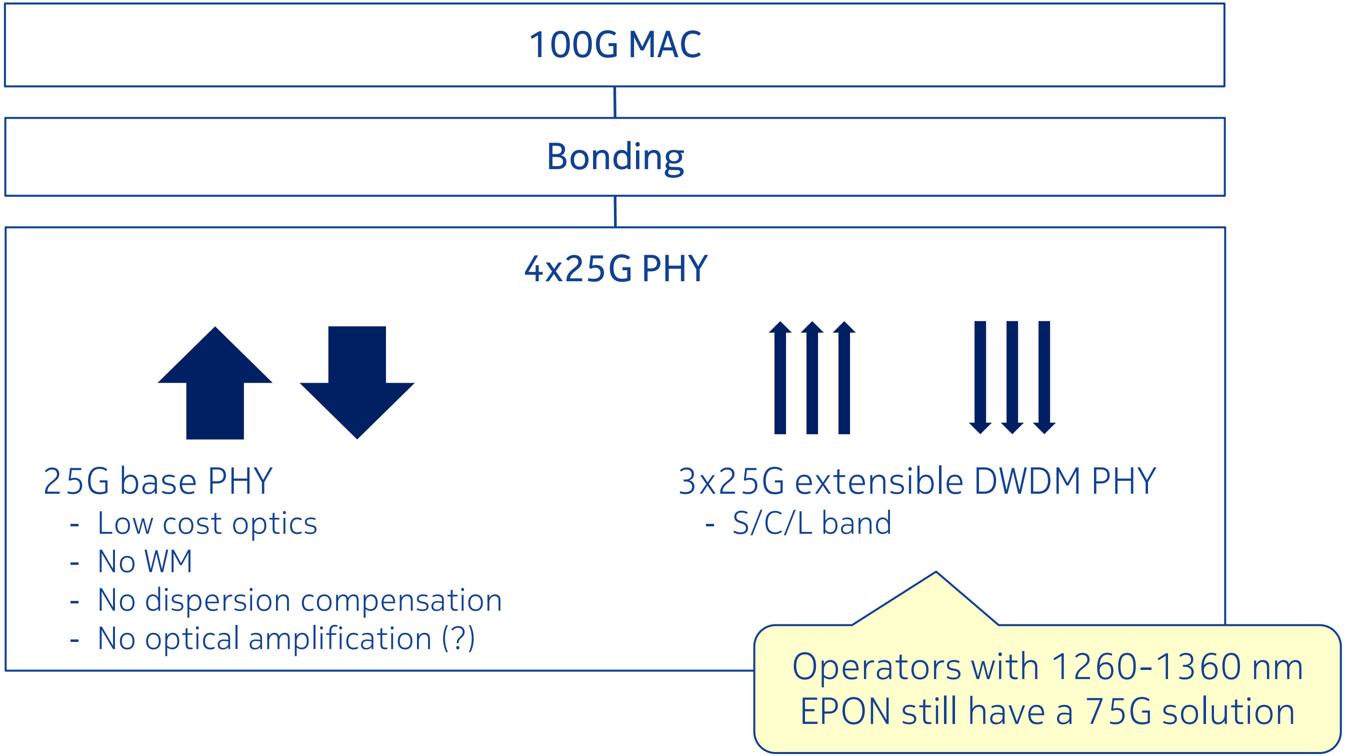
Result 100G EPON PAYG architecture starting with low cost 25G base PHY



Defer until 2nd wavelength pair:

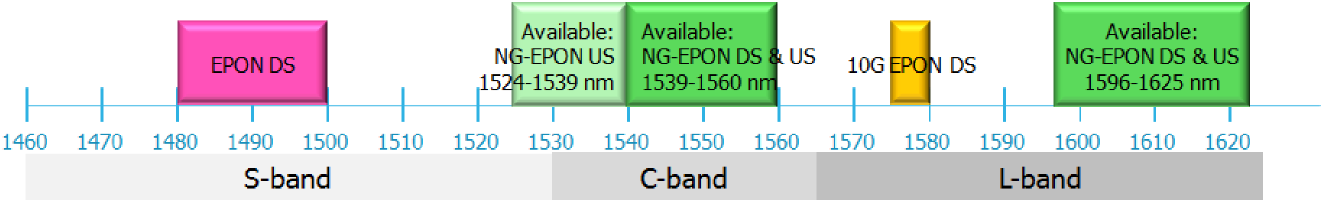
- WM
- expensive optics in ONU and OLT
- dispersion compensation
- optical amplification (?)

25G base PHY under 100G MAC

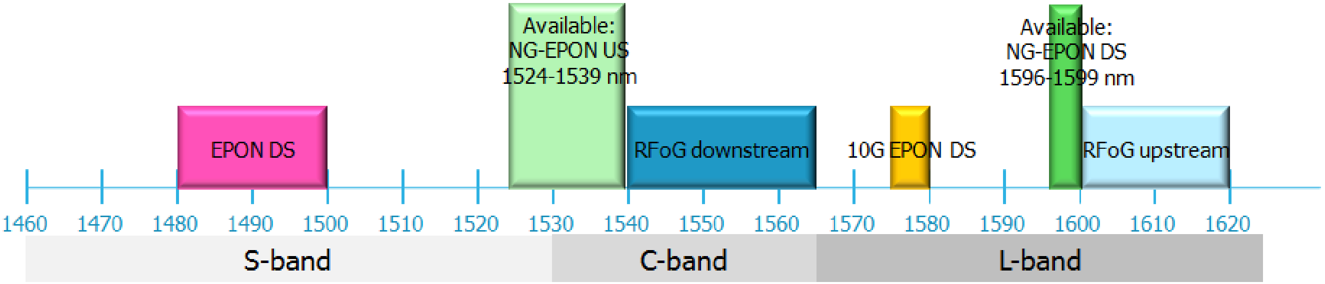


Possible available C/L spectrum for wavelength pairs 2-4

Co-existence:
- EPON
- 10G EPON

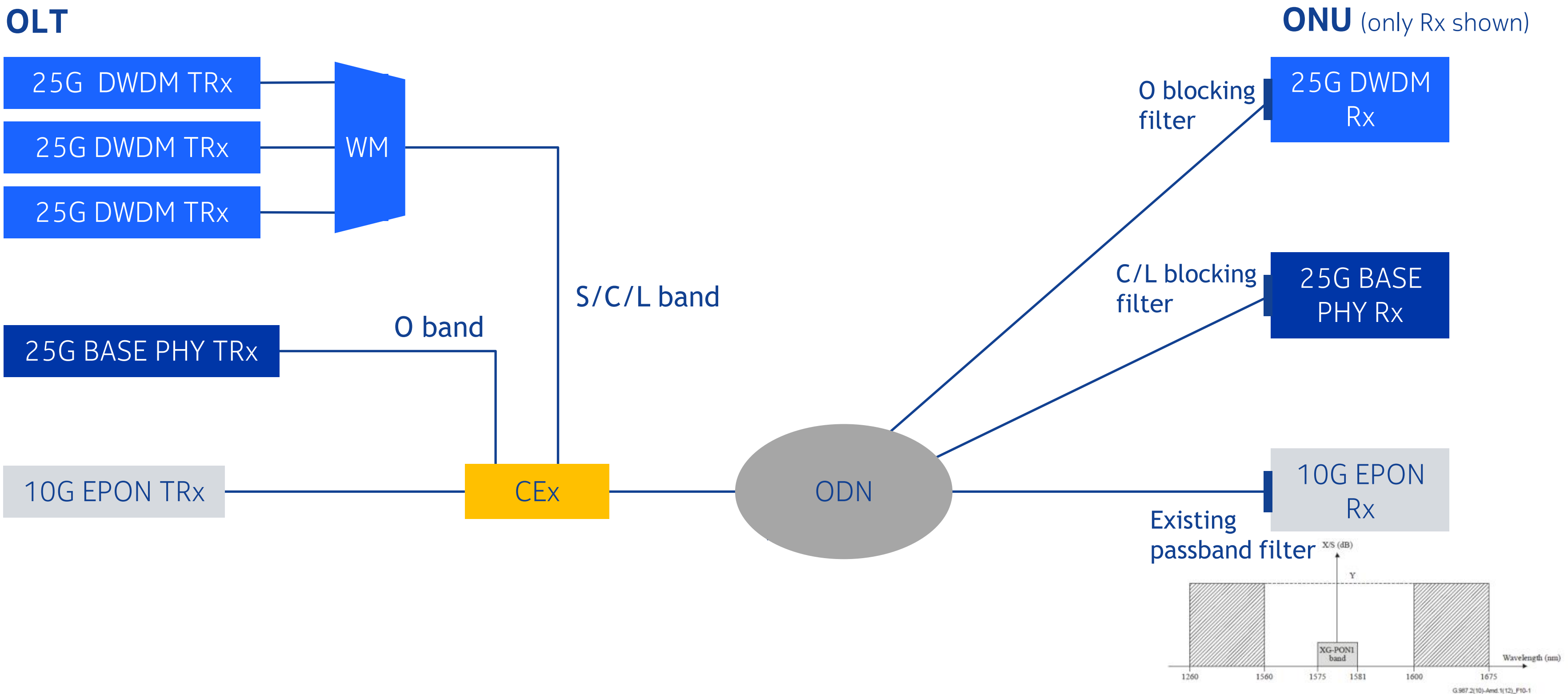


Co-existence:
- EPON
- 10G EPON
- RFoG



Reference: ngepon_0115_harstead_03a.pdf. FEXT and/or NEXT analysis required to verify.

With co-existence support for 10/10 EPON



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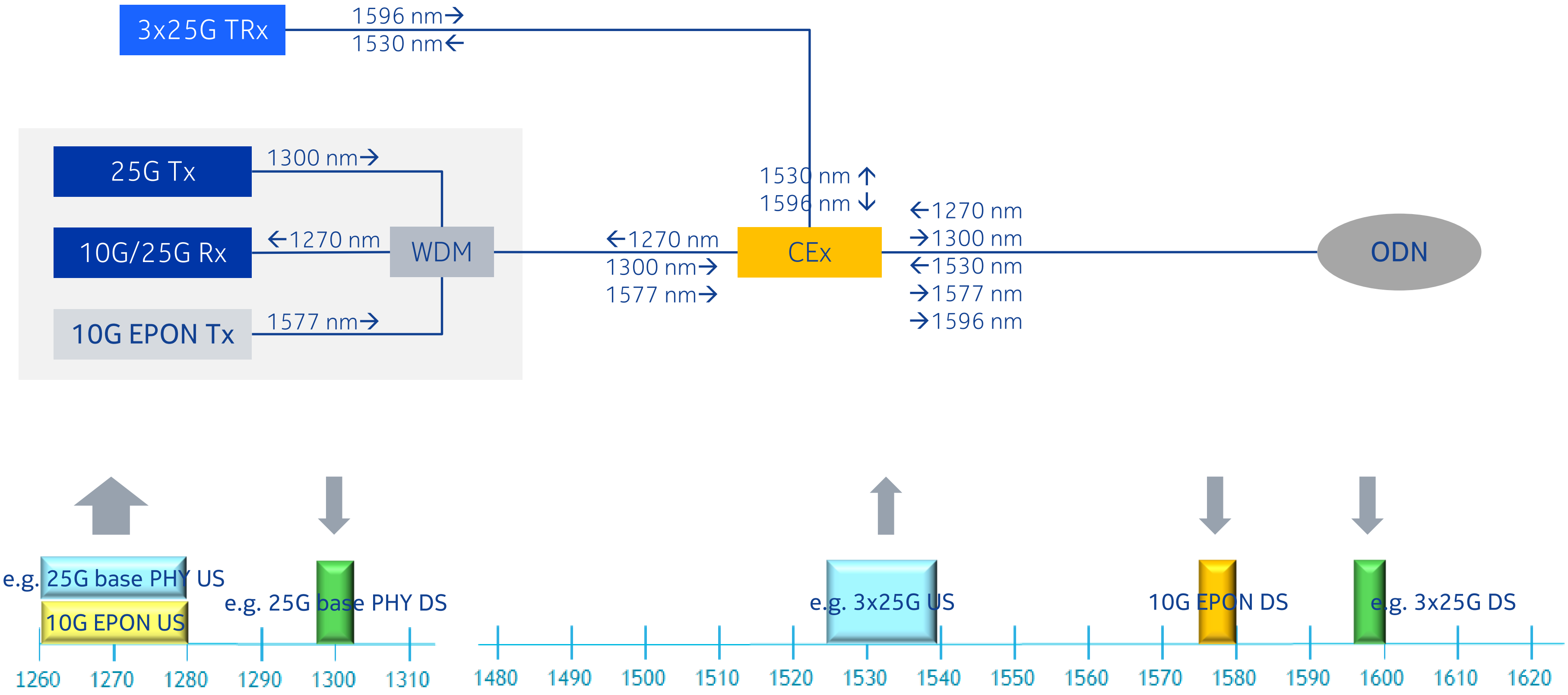
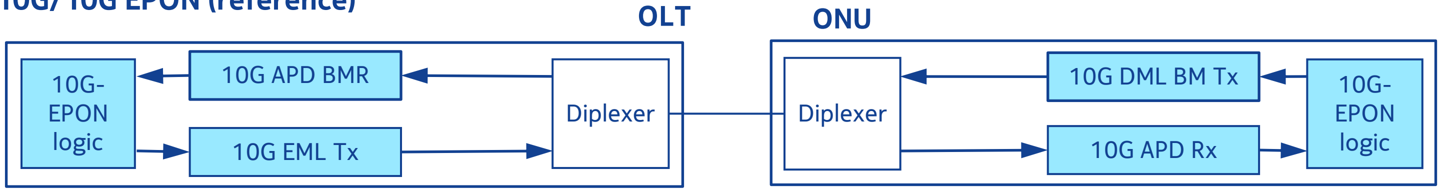
CEx: Should be no more complex than the NG-PON2 CEx, maybe simpler



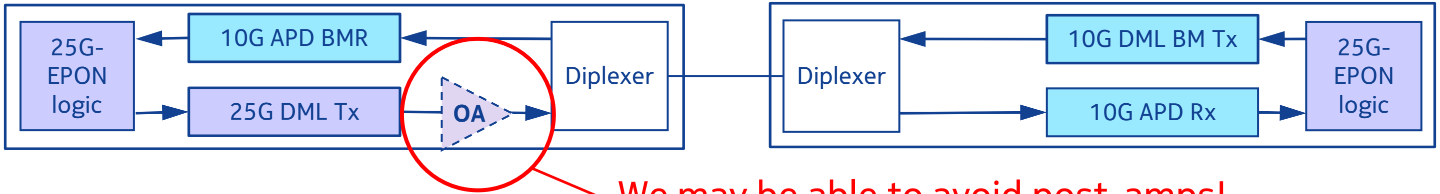
25G base PHY: cost premium vs. 10G EPON (duobinary detection)

10G 25G

10G/10G EPON (reference)



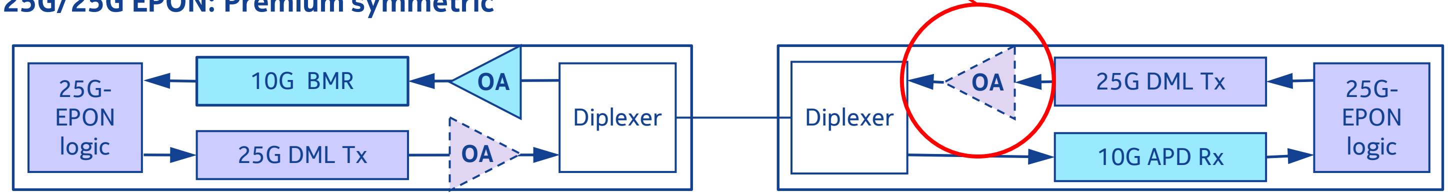
25G/10G EPON: Residential. Re-use 10G EPON upstream.



2.5x more ⇩ bandwidth at "smaller" premium

We may be able to avoid post-amps!

25G/25G EPON: Premium symmetric



2.5x more ⇧⇩ bandwidth at "larger" premium

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Estimated launch power requirements (duobinary detection)

		25G downstream 10G APD receiver in ONU	Needed for premium symmetric only: 25G upstream 10G APD receiver in OLT	25G upstream SOA-pin receiver in OLT
10GBASE-PR(X) EPON Rx sensitivity		-29.5 dBm (U4)	-29 dBm (D4)	-30 dBm [1]
Penalty, 25G duobinary detection vs. 10G NRZ [2]		5.5 dB	5.5 dB	5.5 dB
25 Gb/s Rx sensitivity, duobinary detection		-24 dBm	-23.5 dBm	-24.5
Factor in improved FEC coding gain		- 1 dB	0 dB	0 dB
Transmitter and dispersion penalty (as 10G EPON)		+1.5 dB	+1.5 dB	+1.5 dB
Required min. launch powers and transmitter [3]		25G OLT transmitter	25G ONU transmitter	25G ONU transmitter
PR-30 loss budget[4]	+29 dB	5.5 dBm: DML, no post amp	7 dBm: post amp	6 dBm: DML, no post amp
PR-40 loss budget[4]	+33 dB	9.5 dBm: post amp	11 dBm: post amp	10 dBm: post amp

[1] Assume at least 1 dB improvement for SOA+p-i-n vs. APD.

[2] D. van Veen, V. Houtsma, H. Chow, “Demonstration of Symmetrical 25 Gbps Quaternary PAM /Duobinary TDM-PON with multilevel interleaving of users”, ECOC 2015, and X. Yin et. al., “25Gb/s 3-level Burst-Mode Receiver for High Serial Rate TDM-PONs”, OFC 2015.

[3] For reference, PR40 minimum upstream launch power = 6 dBm.

[4] The base PHY diplexer loss is implicitly included in the loss budget.

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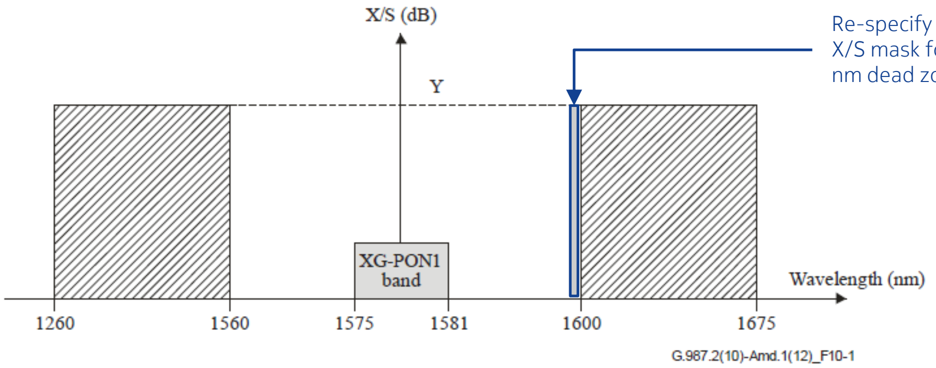
Conclusions

- A 25G base PHY for 100G EPON is proposed as a low cost 1st wavelength pair.
- Can be realized by design choices that defer cost and complexity to the 2nd wavelength pair:
  1. Defer DWDM (continue the proven PON tradition of sloppy wavelengths)
  2. Choose O-band for upstream
  3. Choose O-band for downstream
- Increases the probability that a lower cost per bit than 10G EPON can be achieved, and sooner.

Backup

10G EPON ONU co-existence to O-band downstream interferers

- XG-PON ONU tolerance to interferers from 1560 nm down to 1260 nm.
- Assume the same filter characteristics for 10G EPON



Re-specify the XG-PON1 ONU X/S mask for symmetrical +15 nm dead zone (i.e. to 1596 nm)

Class	Y (dB)
N1, E1, N2a, E2a	21.5
N2b, E2b	15

S: Received power of basic band.
X: Maximum total power of additional services received in the blocking wavelength range.
X/S: In the mask (hatching area) should not cause the XG-PON receiver to fail to meet its sensitivity requirements.

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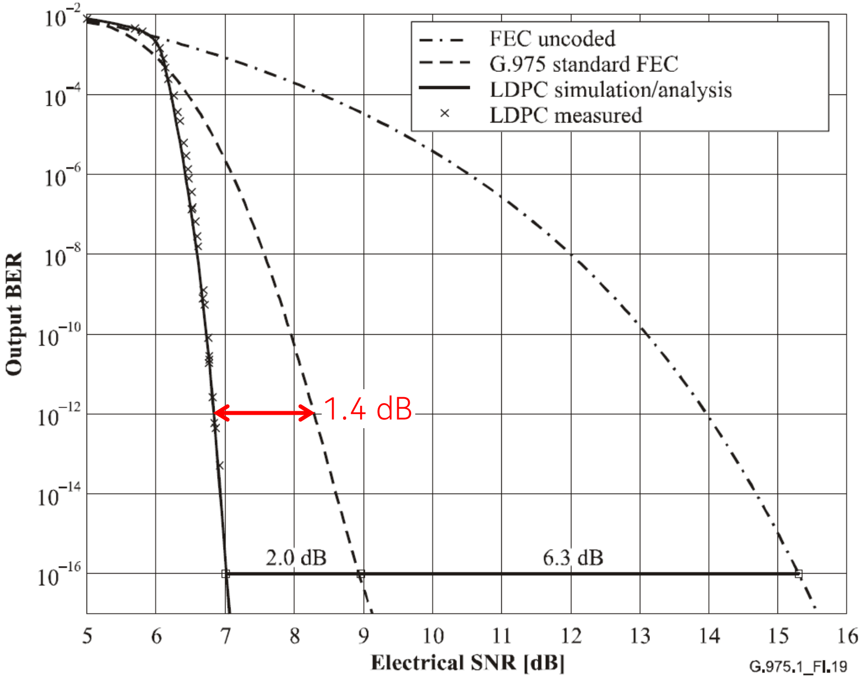
Improved coding gain with LDPC FEC

Example: R-S (G.975) versus LDPC with bit flipping decoder, 6.7% OH



RS-FEC versus LDPC FEC

- Replacement of RS-FEC by LDPC code enables gains of 1-2 dB (example with 1.4 dB@1e–12)
- Assumes simple low-complexity hard decision LDPC decoder
- With more advanced decoders (higher complexity), **additional** gains of up to 1 dB feasible.

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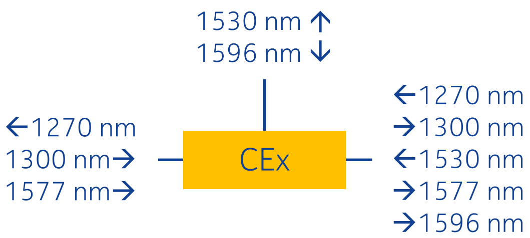
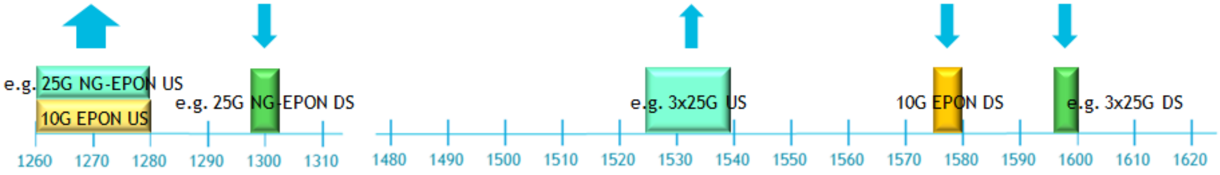
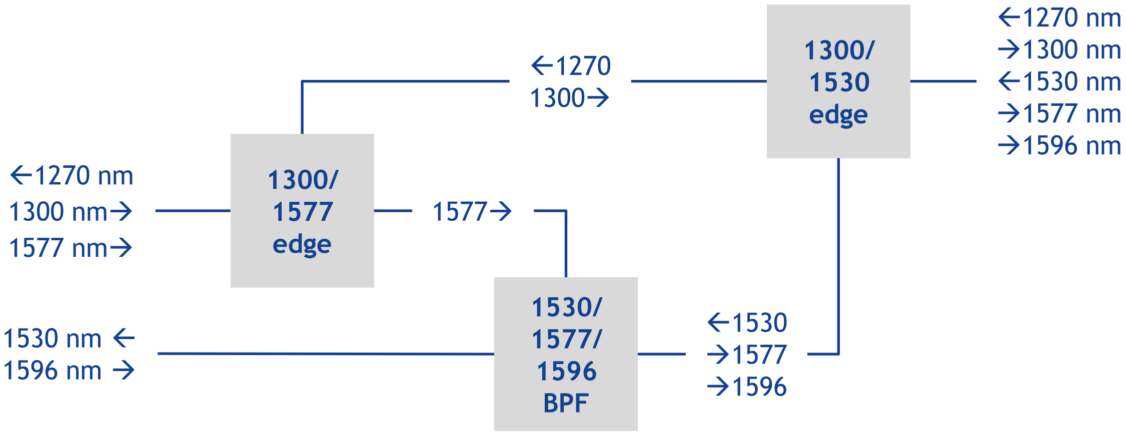
CEx implementation (example)





Implementation

- 3 ports
- Filters:
  - Two coarse edge filters
  - One bandpass filter
  - Maximum 3 filters in series (1577 nm only)
- Should be no more complex than NG-PON2 CEx



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