25G TDM PON overview

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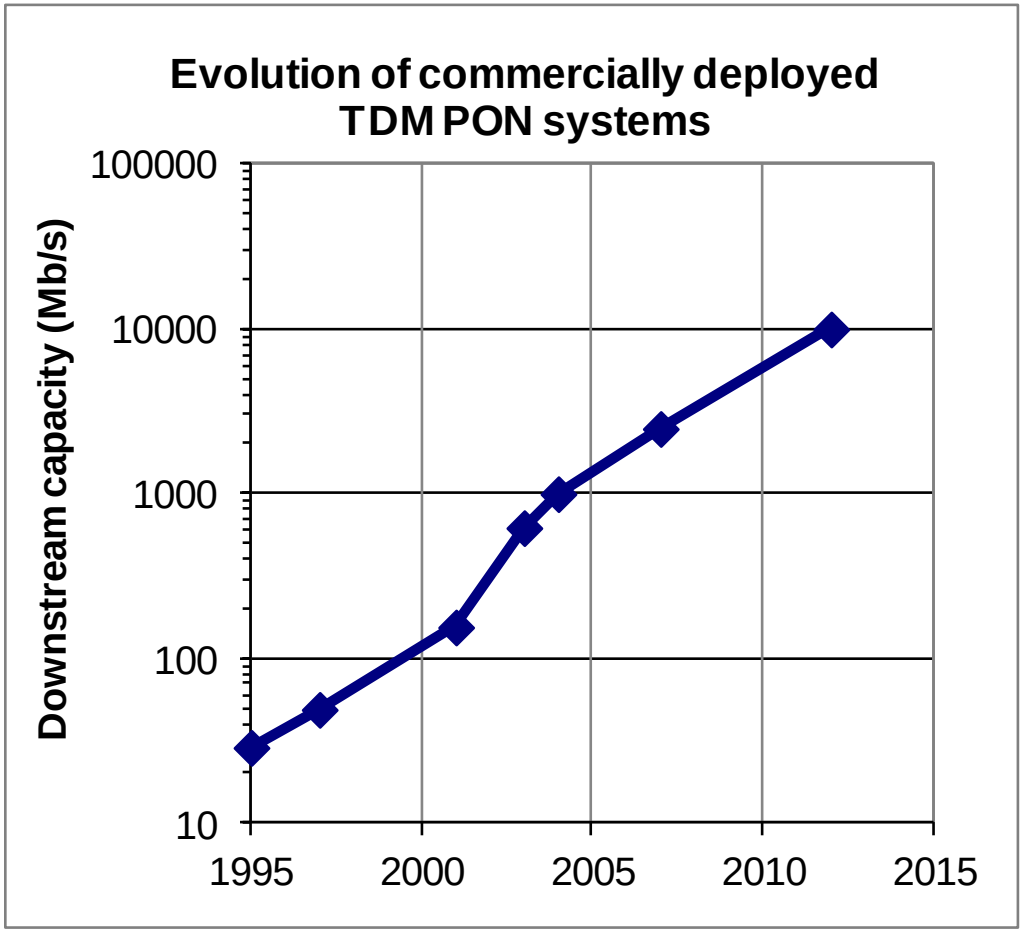
Background: Evolution of TDM PON bit rates

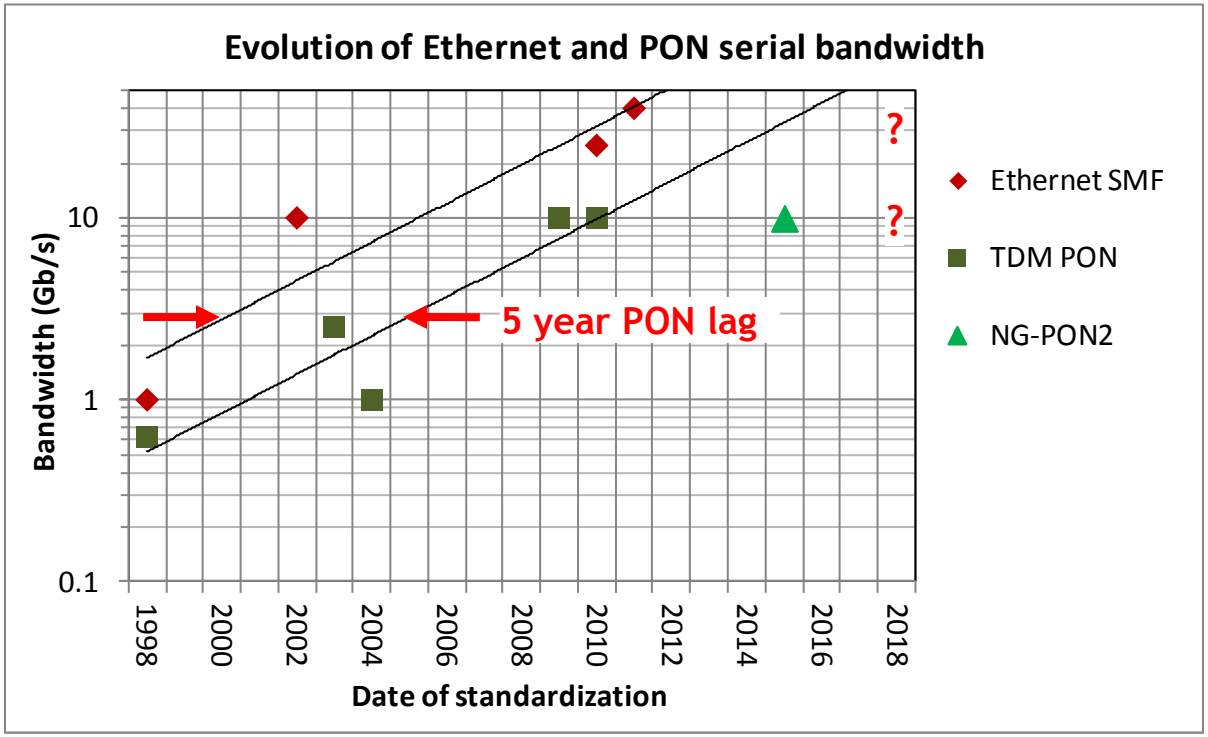
- Virtually all deployed PONs are TDM PONs
- TDM PONs use simple, non-tunable optics
- Up to 10G, at each increase in speed, TDM PON technologies successfully overcame 3 main challenges without resorting to WDM:
    1. higher speed optics and electronics;
    2. higher optical transmit power and/or improved receiver sensitivity;
    3. mitigation of chromatic dispersion.
- But, is there a “sound barrier” at 10G?



Trend: Up to 10G PON, TDM PON serial bit rate has doubled on average every 2 years

Evolution of serial bit rates (Ethernet and PON)

- Optical transport design principle: employ maximum practical serial bit rate (i.e. before hitting the steep part of the cost curve) before resorting to WDM.
- If there was a “sound barrier” at 10G, 802.3 has already broken it

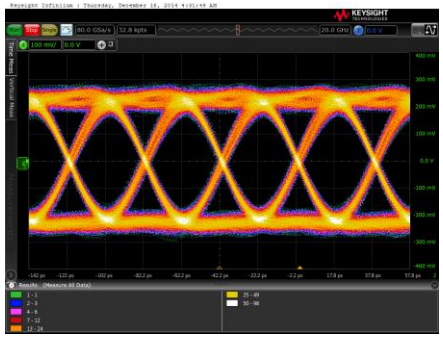


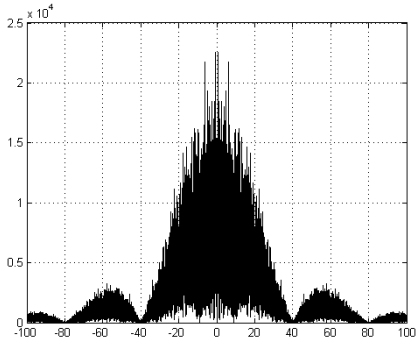
- An NG-EPON adoption of 10G wavelength stacking would reflect a deep pessimism about the availability of practical high speed optics, and out of alignment with the rest of 802.3.

Modulation Options for NG-EPON

NRZ OOK

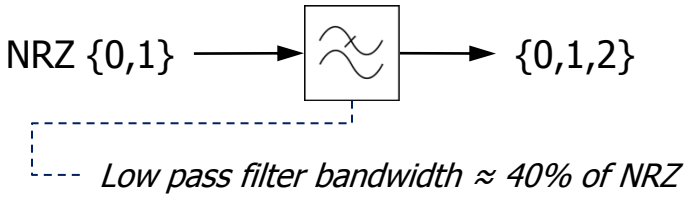
NRZ {0,1}

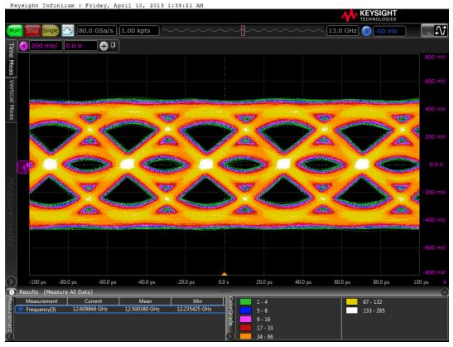


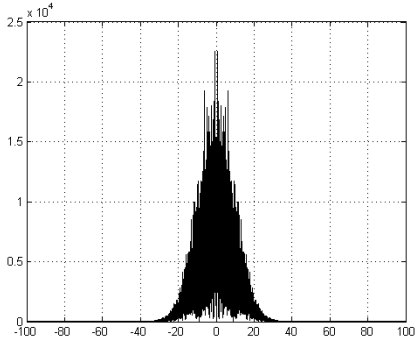


Duobinary (electrical): low pass filter approximation

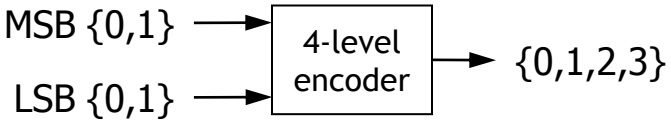
Refer to (ngepon_1114_harstead_01b)



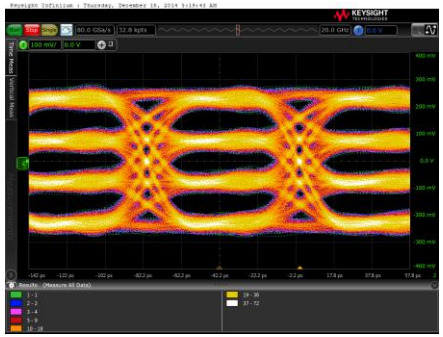


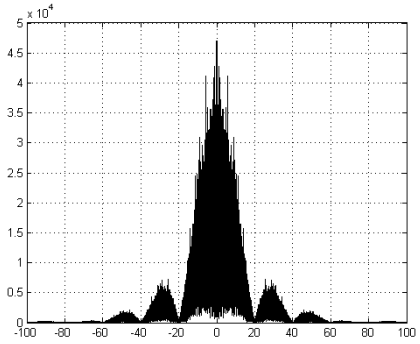


PAM4



Possible re-use of PAM4 from 100GBASE-KP4, 802.3bs CDAUI-8 and 8x50G 10 km SMF



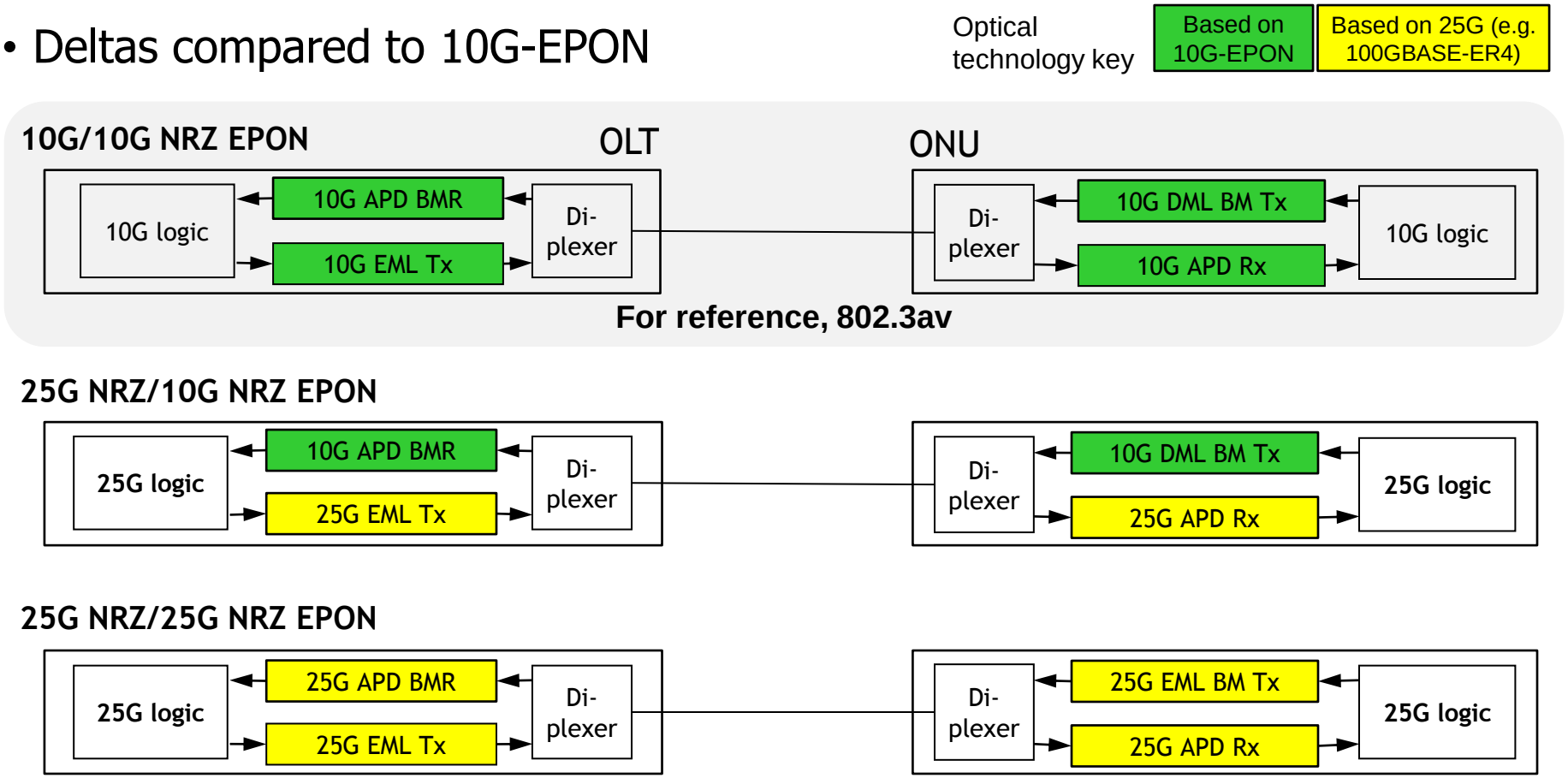


Time

Frequency

25 Gb/s TDM PON: NRZ Modulation

- Deltas compared to 10G-EPON

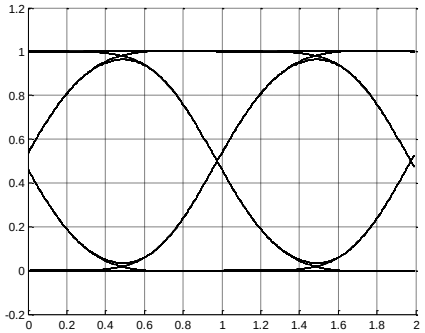


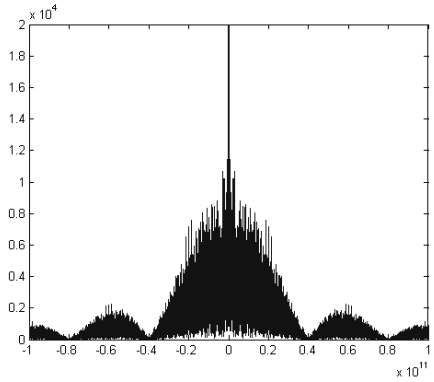
- 25 Gb/s optics required in the ONU and OLT
  - Potential re-use of 25 Gb/s 100GBASE-ER4 optics

Duobinary modulation: reduces spectrum by half

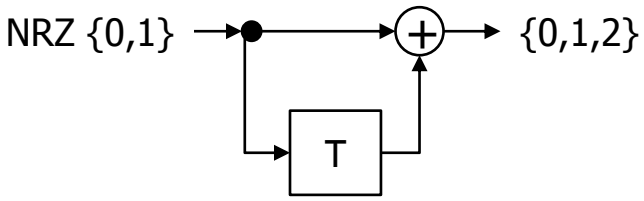
NRZ OOK

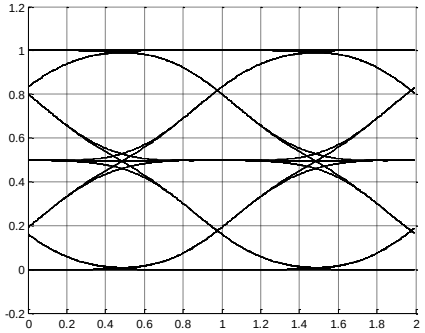
NRZ {0,1}

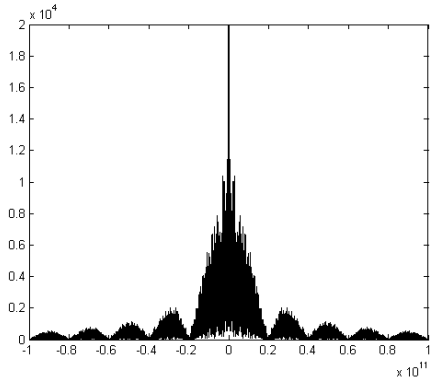




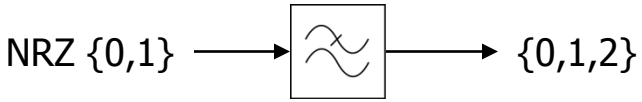
Duobinary*: delay and add filter

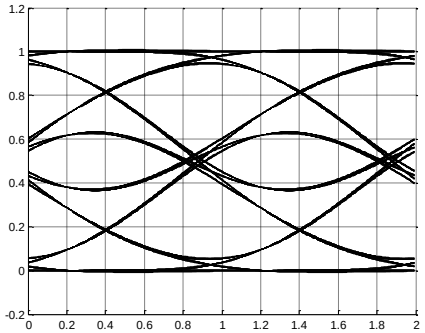


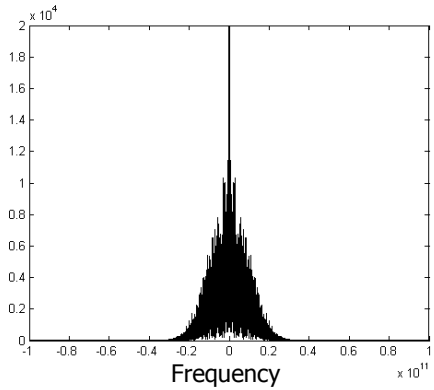




Duobinary*: low pass filter approximation





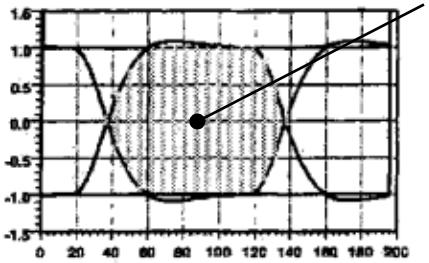


*These are 3-level "electro" duobinary modulations, not to be confused with optical duobinary

Optimizing ISI to create a duobinary signal

Figures from E. Säckinger, Broadband Circuits for Optical Fiber Communication, 2005

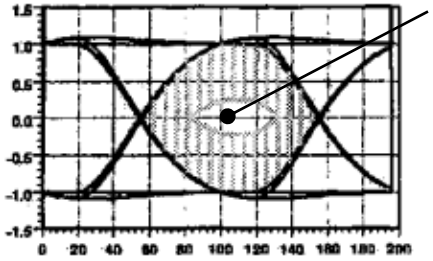
Low signal distortion, but too much noise



NRZ eye

$BW_{3dB} = \frac{4}{3}B$

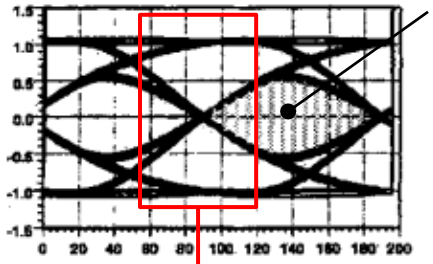
Optimum



NRZ eye

$BW_{3dB} = \frac{2}{3}B$

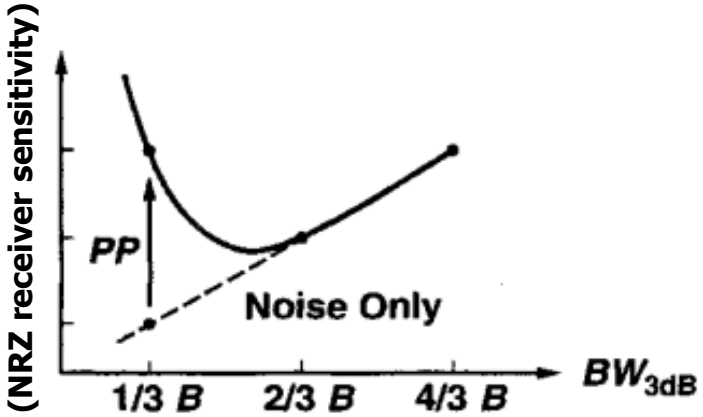
Low noise but too much ISI



NRZ eye

$BW_{3dB} = \frac{1}{3}B$

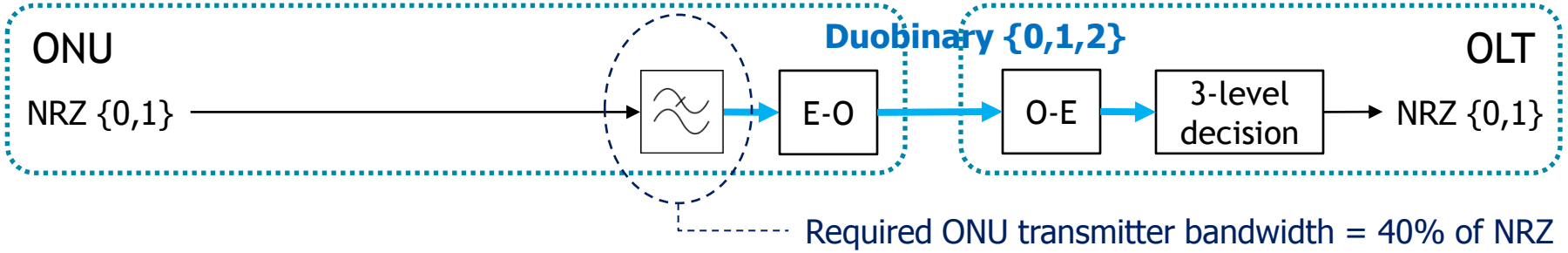
But at this bandwidth, ISI creates a duobinary eye!



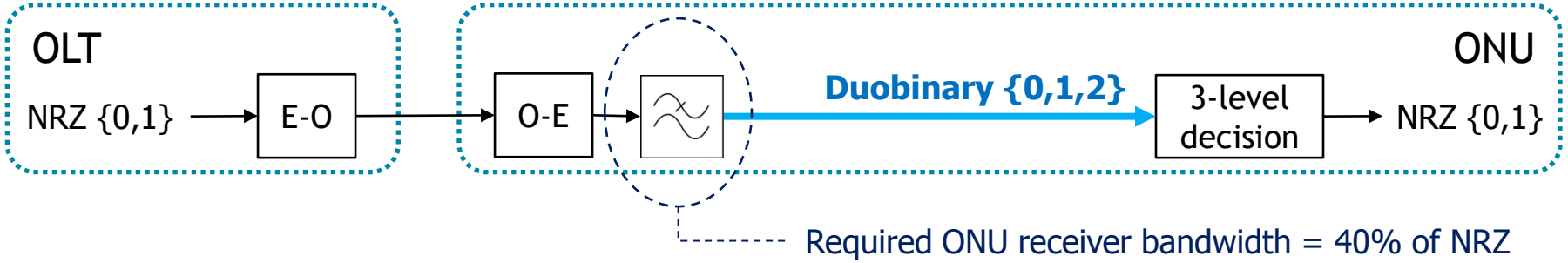
Partitioning duobinary functions in TDM PON

Duobinary functions

Transmitter-encoded duobinary



Receiver-encoded duobinary

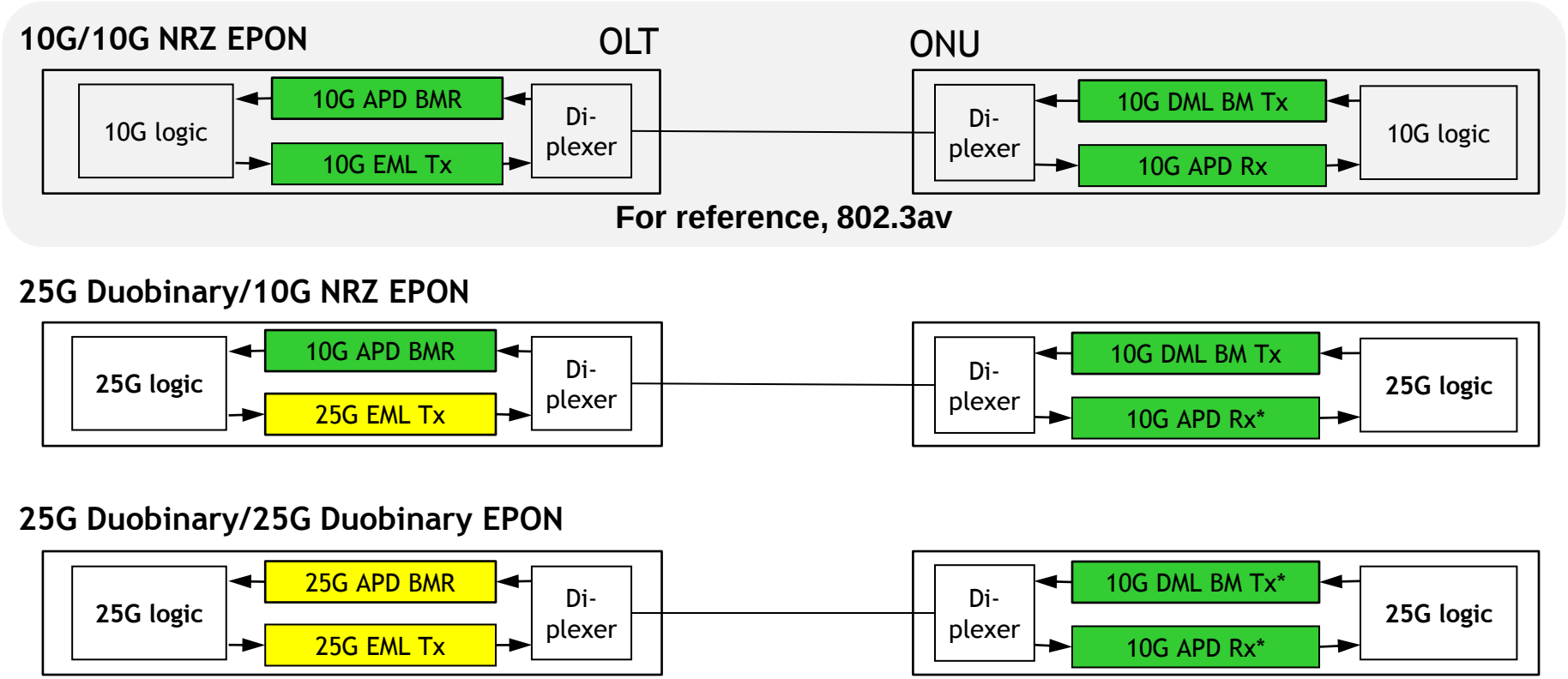


Can get 25 Gb/s symmetric transmission with 10 Gb/s components in the ONU!
Can get 40 Gb/s symmetric transmission with 25 Gb/s components in the ONU!

25 Gb/s TDM PON: Duobinary Modulation

- Deltas compared to 10G-EPON

Optical technology key: Based on 10G-EPON | Based on 25G (e.g. 100GBASE-ER4)



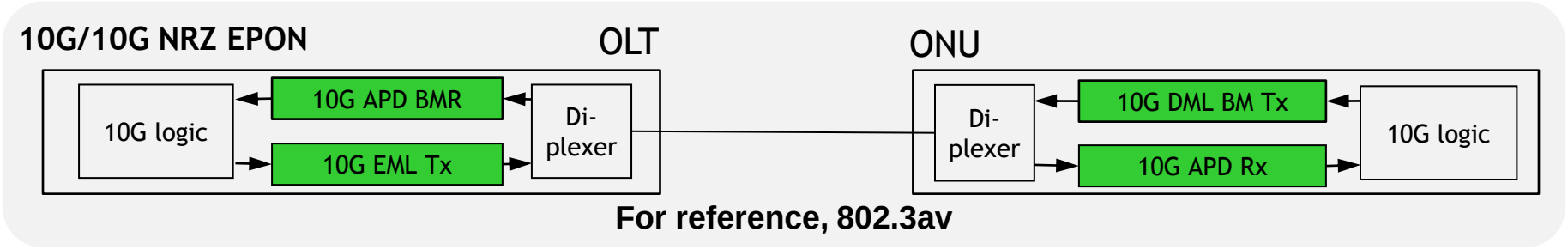
*Low pass filter function

- In the ONU, same 10G optics as 10G-EPON
- Potential re-use of 25 Gb/s 100GBASE-ER4 optics in the OLT

25 Gb/s TDM PON: PAM4 Modulation

- Deltas compared to 10G-EPON

Optical technology key: Based on 10G-EPON | 25G, or stretch 10G components



*Requires linearized driver

- Target = same optics as 10G-EPON
  - Might be possible to stretch 10 Gb/s components (to be confirmed)

NRZ, duobinary, and PAM-4 modulation comparison

All 3 modulation types are technically feasible, but will have different cost and performance, which will be predominantly determined by these attributes:

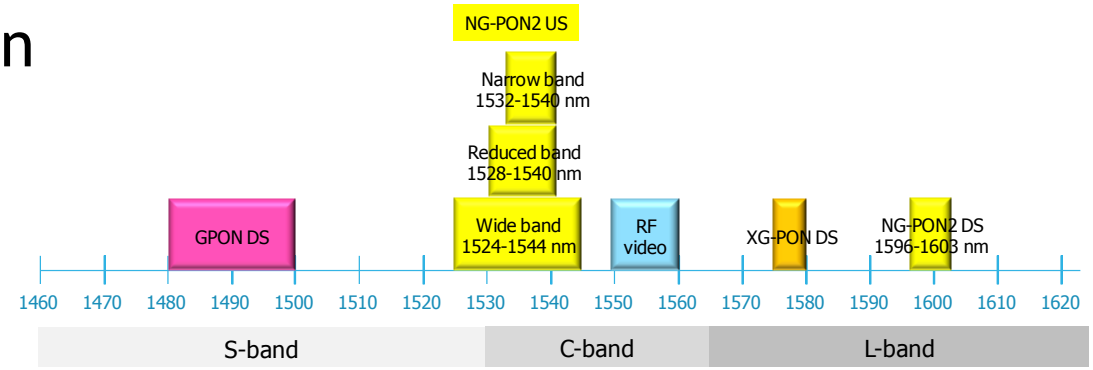
Attributes at 25 Gb/s	NRZ	duobinary	PAM-4
Required speed of optical components in the ONU (Gb/s)	25	10	10-12.5
Approx. back-to-back receiver sensitivity penalty vs. NRZ (dB)	-	1.5	4.0
Dispersion tolerance, EML, 1 dB penalty (ps/nm)*	190	260	500
Transmitter linearity required	no	no	yes
Electronics simplicity	+++	++	+

*simulated values to be confirmed

For more detail, refer to ngepon_0115_houtsma_01

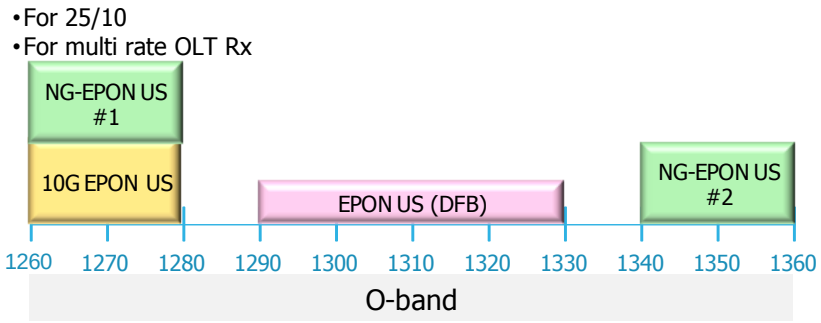
NG-EPON wavelength plan

For reference: “The story of the NG-PON2 TWDM PON wavelength plan” (ngepon_0115_harstead_02)

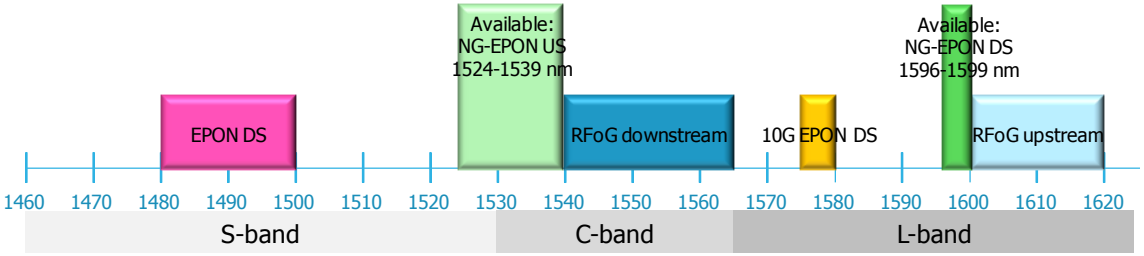


“Proposed NG-EPON wavelength planning decision flow” (ngepon_0115_harstead_03a)

- Some of the initial conditions for NG-EPON are different from NG-PON2
- Higher speeds may be considered, making O-band attractive.
- Therefore IEEE may, or may not, determine a different wavelength plan for NGEPON
- Example scenarios:



Scenario A: O-band is available for upstream (ideal for line rates >10 Gb/s)



Scenario B: O- and E-bands not available; co-existence with RFoG required

Topics planned to cover in future contributions

- 25G upstream burst mode with 10G transmitter in the ONU
- Better validation of dispersion tolerance, which will come into play when we select wavelengths, and at what reaches (if any) we have to worry about dispersion compensation
- What additional dispersion tolerance can we obtain from EDC
- Amplification options for extended loss budgets
- More refinement in the duobinary vs. PAM-4 comparison