100G-EPON wavelength plan proposal

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100G-EPON Challenges

- NG-EPON imposes significant penalties relative to 10G-EPON or 25Gb/s point-to-point transmission applications
- 29dB loss budget for PR-30 PMD and lower RX sensitivity at 25G demands increased TX output power relative to 10G PON
  - 25Gb/s NRZ RX sensitivity is ~4dB less than 10Gb/s NRZ RX
  - 4dB higher TX power virtually precludes use of uncooled lasers without inclusion of optical amplification in the system
  - 12.5GBaud PAM4 or optical duobinary (ODB) modulation have similar reduction in sensitivity relative to 10G NRZ. (*funada_3ca_1_0316.pdf)* More study is needed to determine merit relative to 25Gb/s NRZ.
- Higher bit rate increases ISI due to chromatic dispersion
  - Low TDP 25G transmission over 20km without dispersion compensation is only possible in O-band (*umeda_3ca_1_0316.pdf, slide 11*)
  - 25G DML transmission is enabled in the short side of O-band with zero to small negative dispersion.
  - Low chirp 25G EML TX can be used in the long side of O-band with zero to small positive dispersion.
- As always, lowest possible cost per bit is paramount
  - ONU cost dominates and must be minimized through reduced chip and packaging costs

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Representative power budget

	Unit	Value
Fiber Channel		**PR-30**
Distance	km	20
Split ratio		32
Loss, MAX	dB	29
Transmitter		**4x25G DML**
Bit rate	Gb/s	25.8
Wavelength, MAX	nm	1300
Avg. launch power, MIN	dBm	**8.46**
Extinction ratio, MIN	dB	6
Launch OMA, MIN	dBm	8.62
Transmission dispersion penalty, MAX	dB	2
Receiver		**4x25G APD**
BER with RS(255,223) FEC	1/s	1E-03
Receiver sensitivity, MAX	dBm	-24
ER for RX sensitivity	dB	8
Stressed eye closure penalty	dB	2
Receiver sensitivity OMA, MAX	dBm	-22.38
Stressed receiver sensitivity OMA, MAX	dBm	-20.38

Assumed 4x25G ROSA sensitivity is based on *Nakajima, "High speed avalanche photodiode for 100-Gbit/s Ethernet," Proc. of OFC 2015, M3B.5 (2015)* and is in agreement with suggested 5dB reduction relative to 10G APD as presented in *funada_3ca_1_0316.pdf*.

Approaches to minimize cost

- Use cooled 25G DML technology for ONU
  - Take advantage of negative dispersion in O-band below 1310nm
  - 25G DML chip technology is rapidly becoming well established for 100G-CWDM4 and other 25G point-to-point applications.
  - External modulation (EAM, MZM) requires amplification to compensate modulator insertion loss.
  - Leverage high volume cooled TO-can packaging infrastructure already established for 10G-EPON 1577nm EML OLT.
- Prefer simpler NRZ modulation format over PAM4 or duobinary
  - Avoid the cost and power dissipation of extra electronics and/or optics (see *yi_3ca_1_0316.pdf*)
  - As 25G optics are widely deployed in point-to-point applications over next 2-3 years, the cost differential between 25G and 10G optics will shrink
- Use the largest possible channel spacing consistent with fitting both US and DS channels in O-band
  - 20nm grid (CWDM) pushes OLT wavelengths out of O-band
  - Wider channel spacing reduces mux/demux assembly costs
  - Eliminate need for costly, bulky optical dispersion compensation at the OLT
- Coexist with 10G-EPON for at least 25G and 50G ONU deployments

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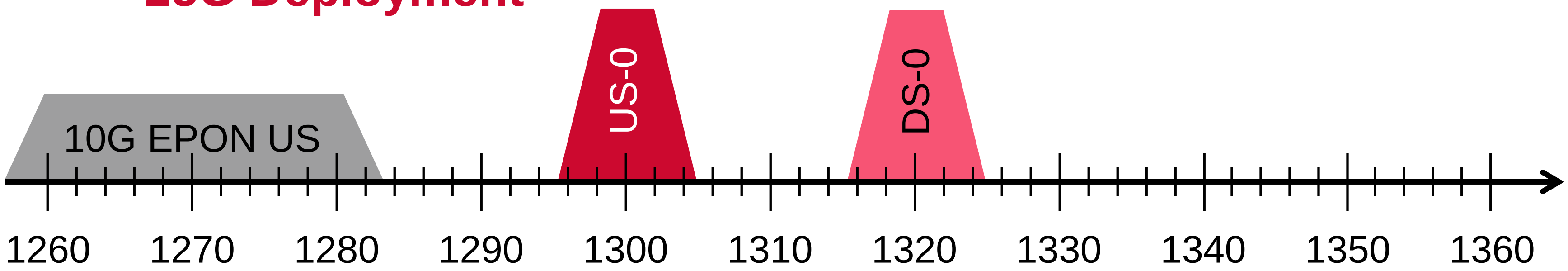
Proposed implementation

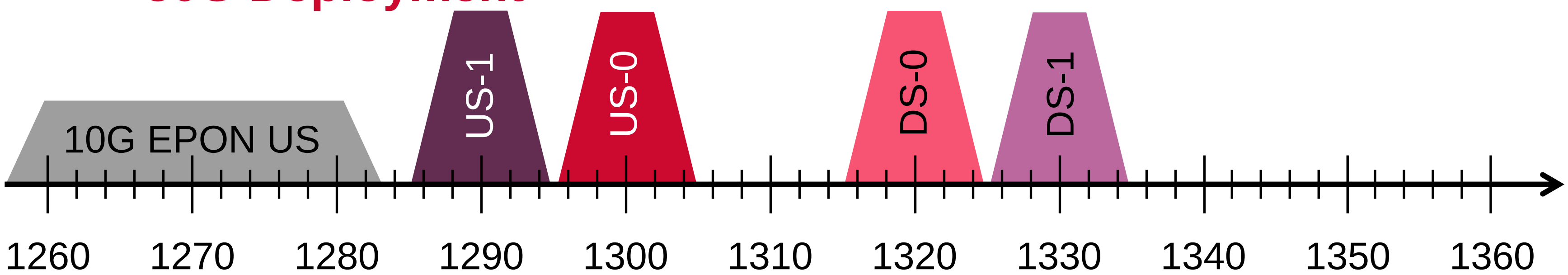
- Take advantage of the smaller wavelength tolerance of cooled sources to shrink grid spacing to 10nm while retaining the cost benefits of TO-can + TFF construction.
  - Passband ~6nm allows > ± 2 nm laser and filter wavelength accuracy
  - Leverage massive GPON and 10G FTTH component infrastructure
  - 50% decrease in TFF angular tolerance is a manageable incremental improvement in assembly technology over 20nm CWDM
- Operate both directions in O-band to avoid the need for optical dispersion compensation with associated cost, space and insertion loss.
  - Maintain at least 20nm guardband between upstream and downstream channels
  - Use low side of O-band (neg. dispersion) to minimize ONU TDP and optical power
  - OLT operating on high side of O-band (pos. dispersion) can use low chirp EML+SOA TX without need for dispersion compensation
- Maintain WDM coexistence with 10G-EPON US through 25G, 50G and *asymmetric* 100G ONU deployments, just not 100G symmetric ONU.
  - Requiring coexistence with GPON or GEPON signals in O-band would significantly increase the cost and complexity of 100G-EPON
  - Coexistence with C/L-band services such as NG-PON2 is possible

Wavelength plan

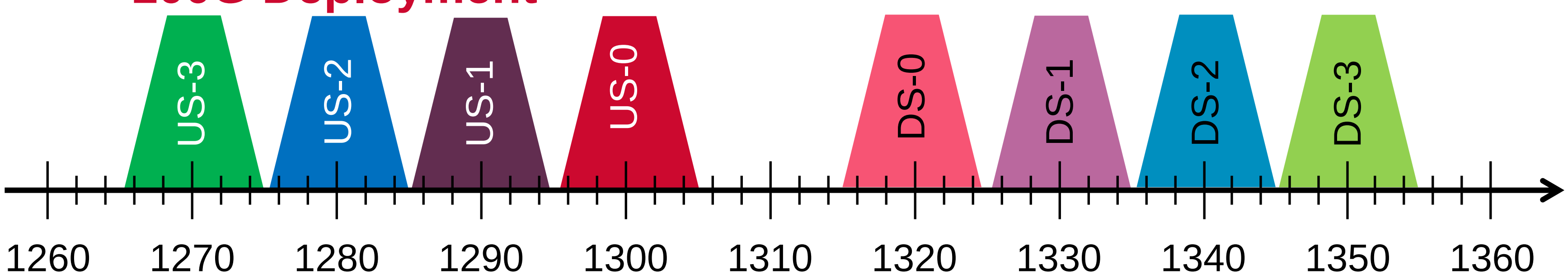
25G Deployment



50G Deployment



100G Deployment



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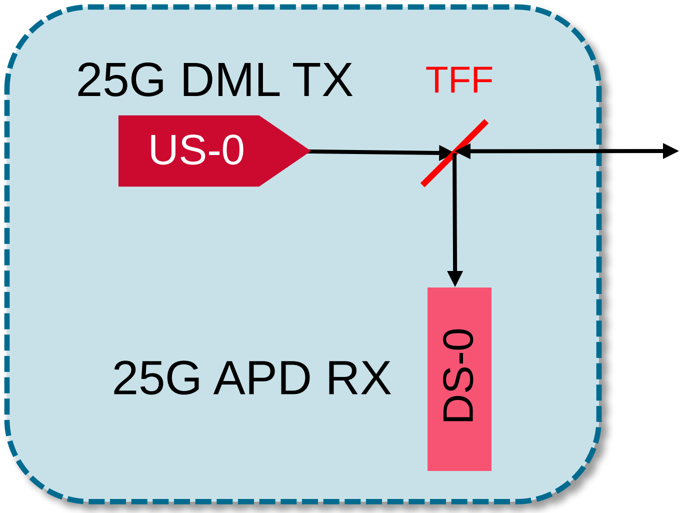
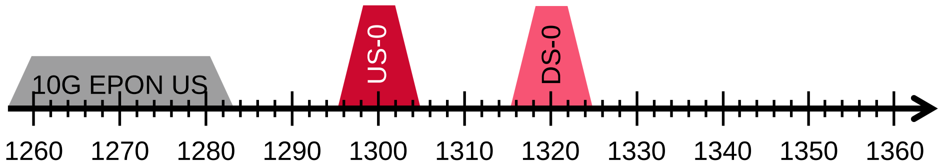
25G ONU



- Standard TO-can BOSA implementation can be used, reducing initial deployment cost
- Lower demux loss increases power margin for first-generation optics
- Coexistent with 10G-EPON upstream



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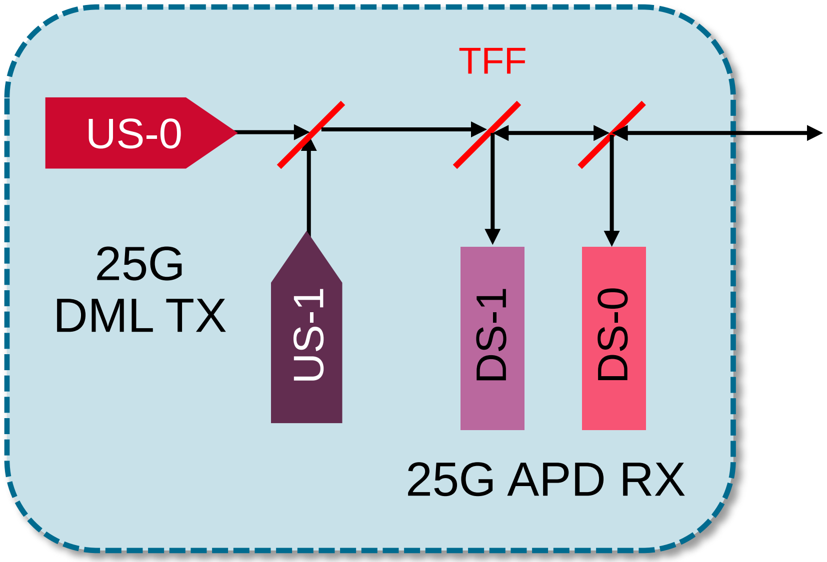
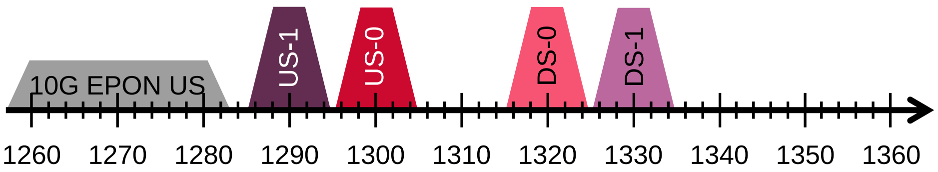
50G symmetric ONU



- 50G BOSA construction is similar to existing TO-can based 40G-LR4 TOSA
- Coexistent with 10G-EPON upstream



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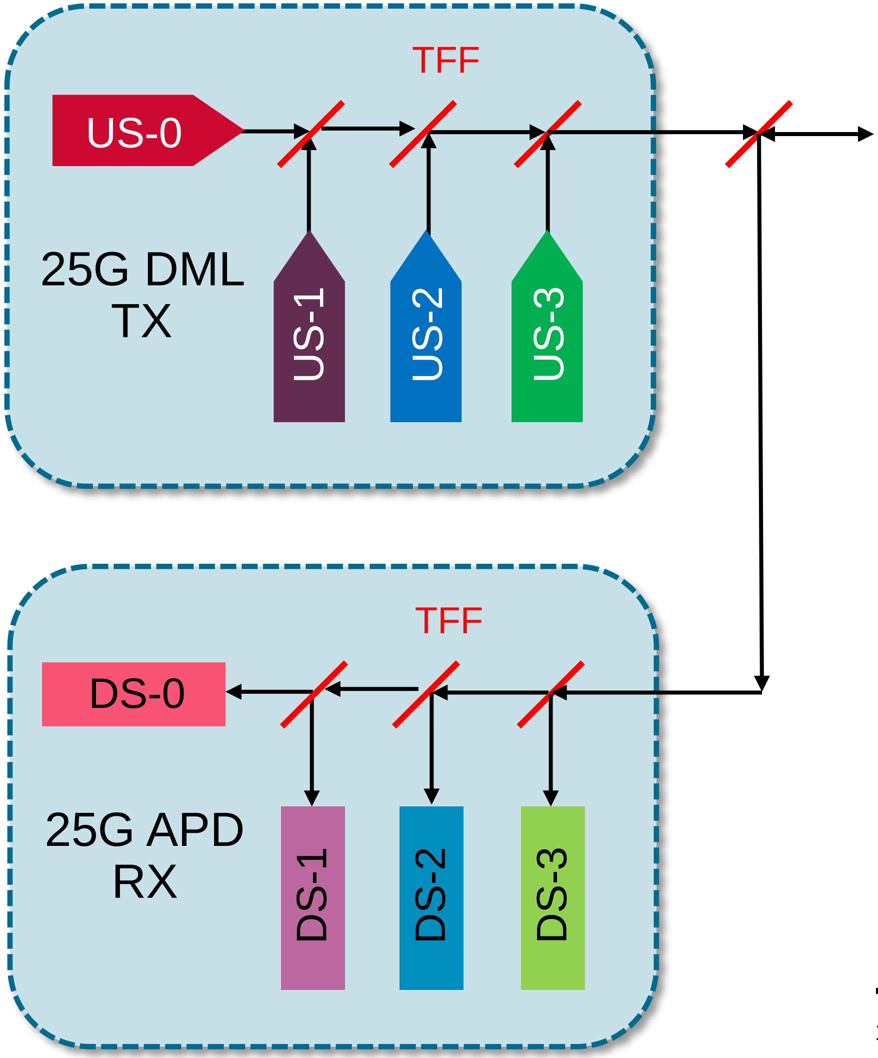
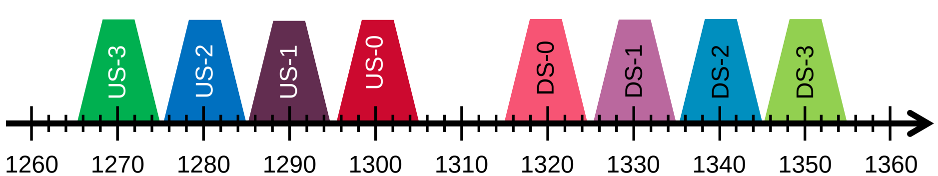
100G symmetric ONU



- 100G TX and RX construction is similar to existing TO-can based 40G-LR4 TOSA
- External diplexer filter with 20nm spacing
- No longer coexistent with 10G-EPON upstream.
- 10G-EPON coexistence can be maintained in asymmetric ONU with 25G or 50G US.



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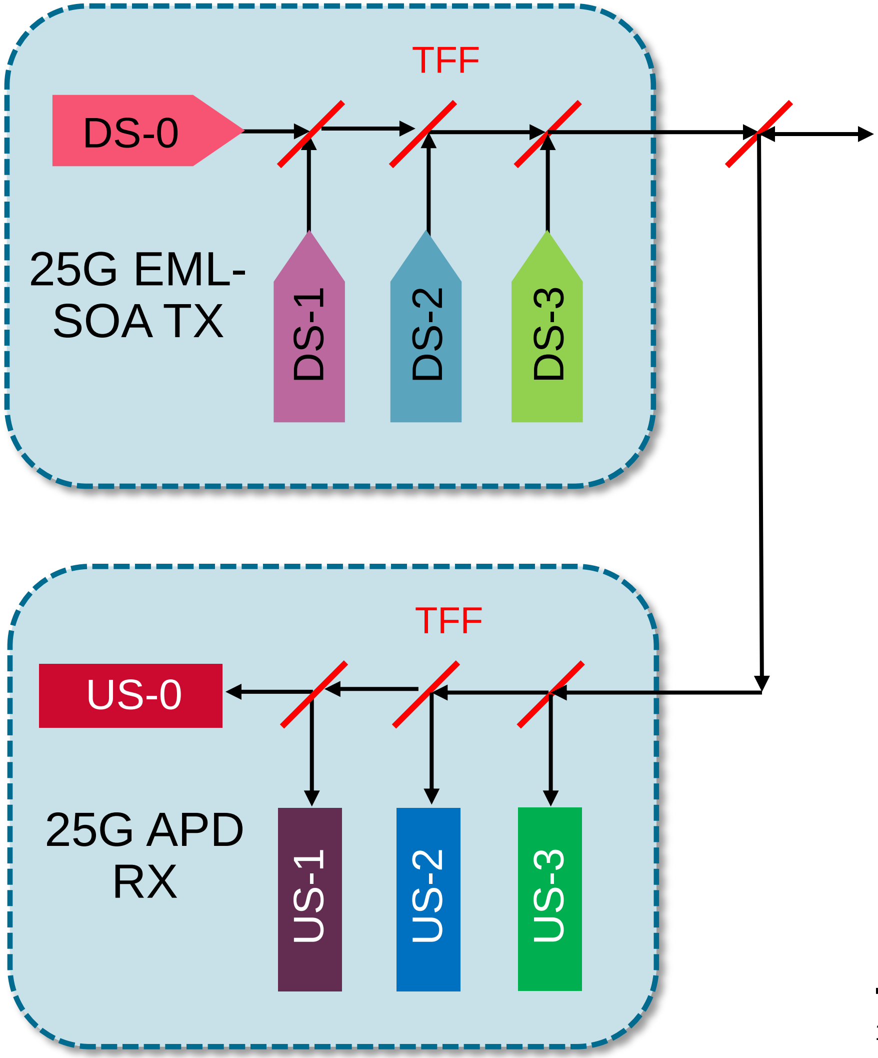
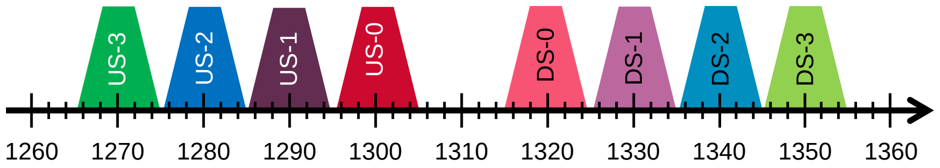
100G OLT



- Positive dispersion for DS wavelengths requires low chirp TX
- Cooled EML has necessary dispersion tolerance but low output power
- Cooled EML-SOA TOSA has necessary power and dispersion tolerance
- Large chip size and high SOA power dissipation may preclude use of TO-can packaging – further study.



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Summary

- Focus on simplest solution that best reduces cost of ONUs
- Cooled TX will be necessary to meet a 29dB loss budget
  - Upstream: Cooled 25G DML, NRZ modulation
  - Downstream: Cooled 25G EML-SOA
- Keep all US and DS wavelengths in low-dispersion O-band
  - Minimize upstream and downstream TDP
  - Avoid need for costly dispersion compensation
  - Take advantage of cooled wavelength control to use 10nm grid for upstream and downstream
  - Leverage massive TO-can based FTTH component infrastructure with incremental improvement in TFF assembly tolerances.
  - Enable WDM coexistence with 10G-EPON through deployment of 25G, 50G and asymmetric 100G ONUs

Thank You