SUMITOMO ELECTRIC

Consideration about wavelength allocation in O-band

Tomoyuki Funada

May 24-25, 2016

SUMITOMO ELECTRIC INDUSTRIES, LTD.

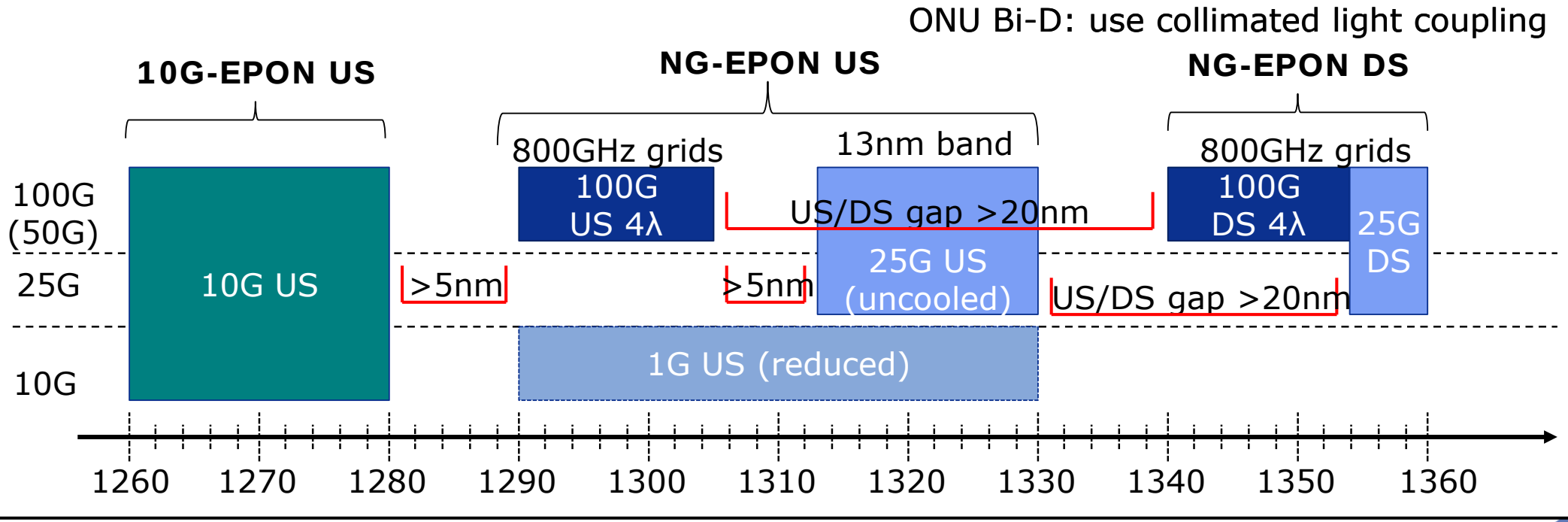
Introduction

- 29dB channel insertion loss with 25Gbps/lane is challenging.
- We showed importance of efficient use of O-band to achieve low Transmitter and Dispersion Penalty (TDP) in previous meeting.
- This presentation adds background information for considering wavelength allocation.
  - ✓ Required wavelength bandwidth for cooled and uncooled Transmitter.
  - ✓ 25G ONU Bi-D structure and relative cost.
  - ✓ channel insertion loss estimation.
  - ✓ Wavelength allocation example in O-band.

Introduction
- Discussion at previous meeting -

- Major questions
  - ✓ Possibility of I-temp. (-40 to +85C) operation with 13nm band.
  - ✓ Cost impact of ONU Bi-D
    - One of our Task Force goal is to have economical 25G solution.

Example shown at previous meeting

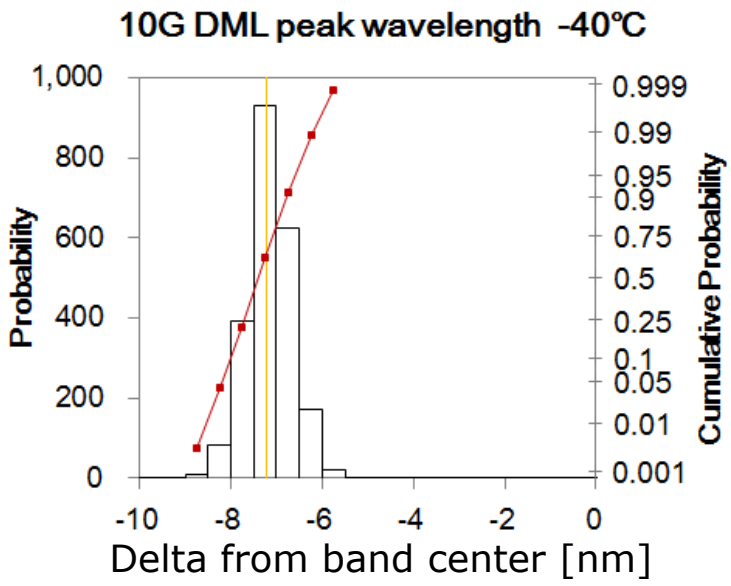


Required wavelength bandwidth
- Uncooled devices -

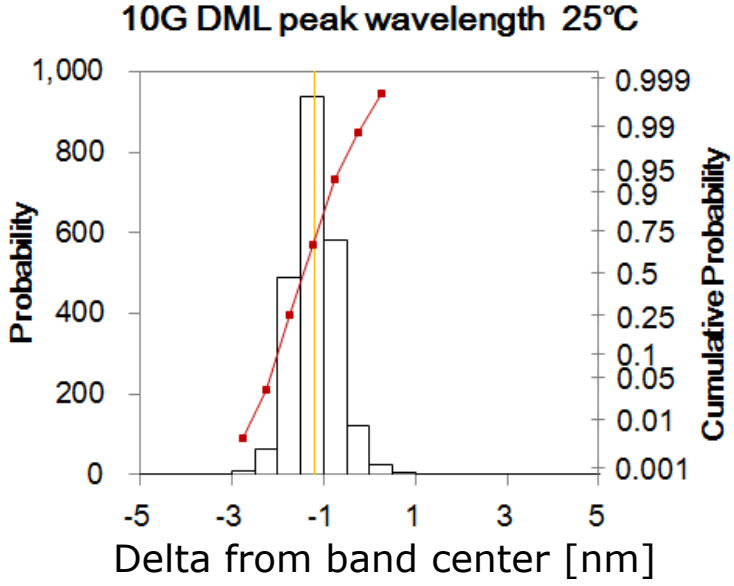
- Uncooled DML
  - ✓ Wavelength distribution at constant case temperature: <±2nm
  - ✓ Temperature dependency; 0.095nm/deg.C
  - ✓ Require 16nm band for I-temp (-40 to 85deg.C).
  - ✓ But we have to take into account that 25Gbps I-temp operation with high extinction ratio (ex. >6dB) is still challenging, and we need further study.

Distribution of 10G DML on CWDM grids

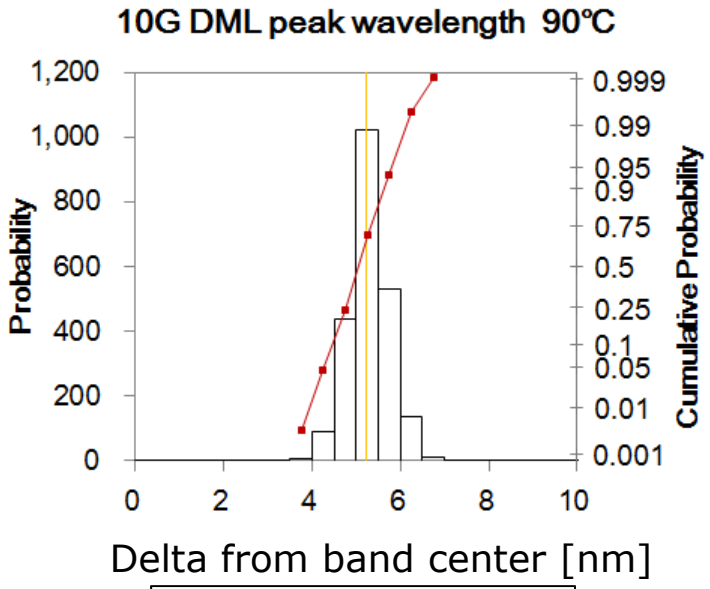
(>2000 samples from 15 wafers, Pout=Constant)



Average: -7.2nm
Sigma: 0.47



Average: -1.2nm
Sigma: 0.47



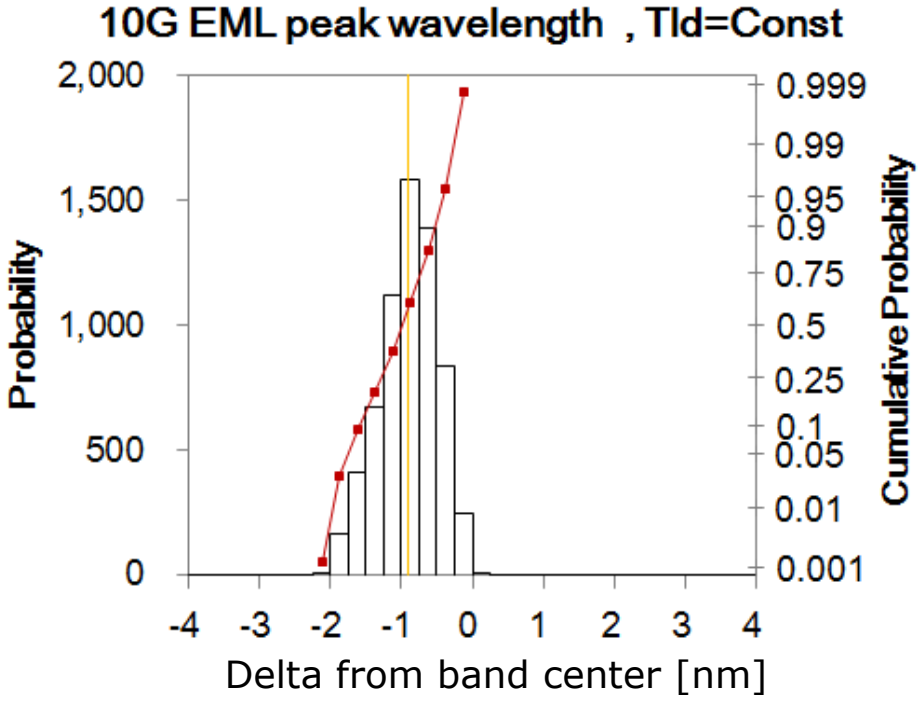
Average: +5.2nm
Sigma: 0.45

Required wavelength bandwidth
-Cooled devices-

- Cooled EML
  - ✓ 4nm bandwidth is enough for cooled EML.
  - ✓ 800GHz grid LAN-WDM (2nm bandwidth)
    - Need loose tuning with TEC temperature or laser current, or loose λ screening
  - ✓ 100GHz or 200GHz grid DWDM
    - Need tight tuning with TEC temperature and laser current, plus λ screening

Distribution of 10G-EPON EML

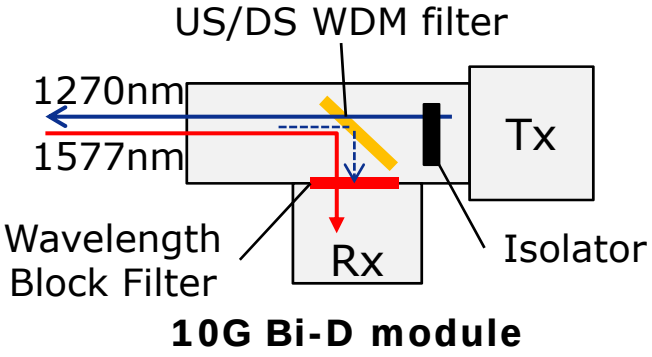
(>8,000 samples from >10 wafers, Pout=Constant)



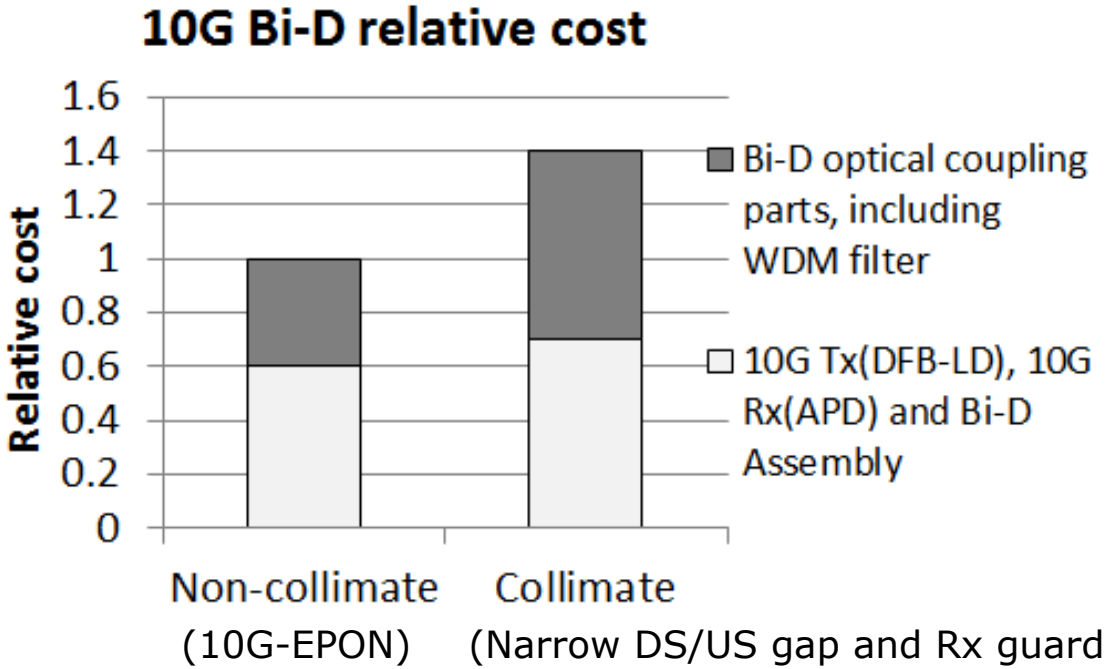
Average: -0.9nm
Sigma: 0.41

Bi-D structure and relative cost
- Collimate and non-collimate -

- Bi-D relative cost
  - ✓ In the case of 10G, collimated light coupling is 1.4 times higher
  - ✓ In the case of 25G, the difference will be smaller as Tx and Rx cost increase
- Benefits of collimated light coupling
  - ✓ Narrower DS/US gap; 25nm (non-collimate: 40nm)
  - ✓ Narrower Rx guard band; ±5nm (non-collimate: ±15nm)
    800GHz grid LAN-WDM filter is also doable
  - ✓ Higher Tx output power; 0.5 to 1dB higher (increase of fiber coupling efficiency)



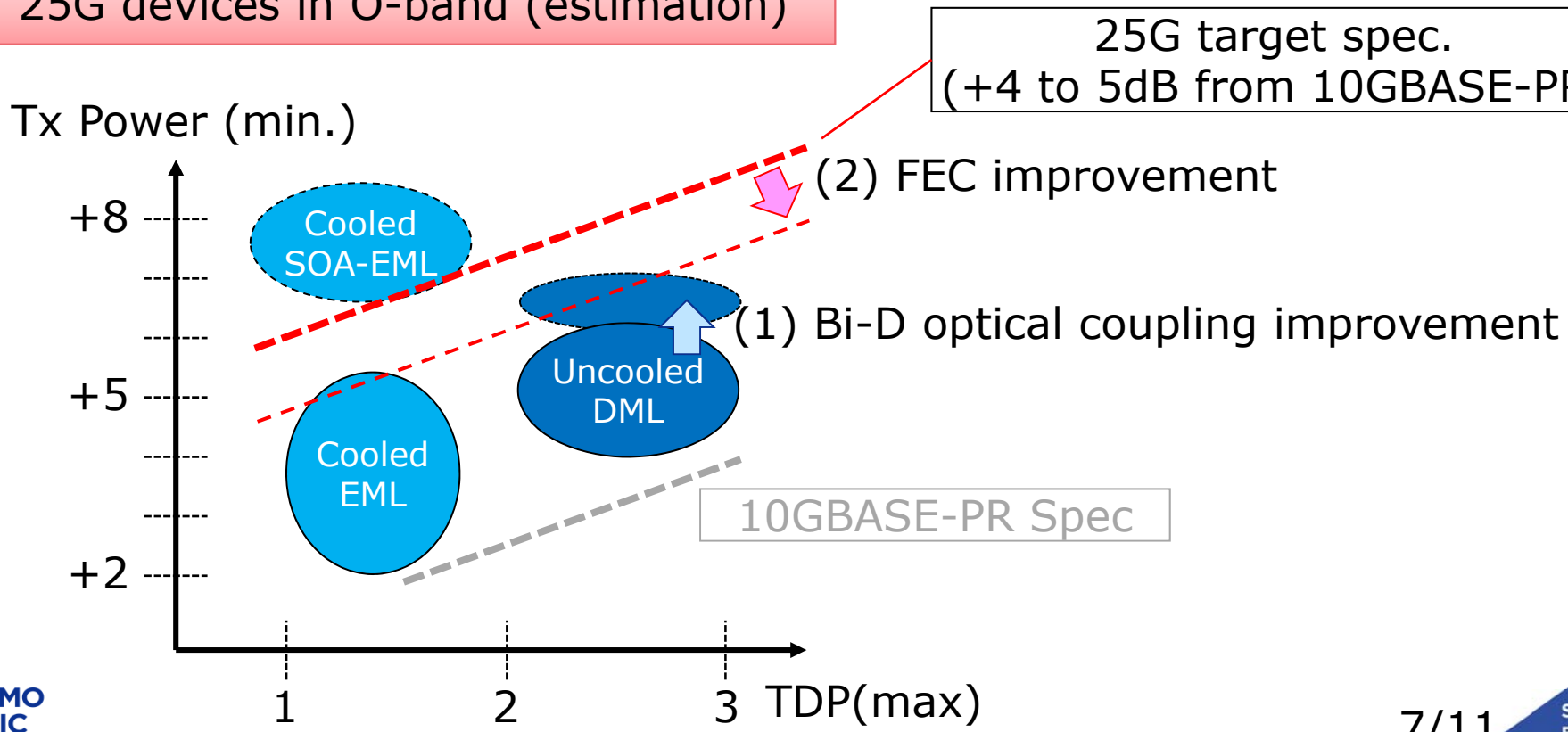
10G Bi-D module



Uncooled DML could be a candidate for 25G system? -Tx Power & TDP of current Tx devices -

- 29dB channel insertion loss, we need Tx with higher power and lower TDP.
  - ✓ Adoptable Tx Power (min) spec. of current uncooled DML ONU Bi-D is 4 to 6dBm.
  - ✓ Potential improvement;
    - (1) Bi-D with higher coupling efficiency optical system (e.g. Collimate); 0.5 to 1dB
    - (2) FEC with higher coding gain; >1dB
- Uncooled DML is on the border line, do we pursue opportunity or do we forget?

25G devices in O-band (estimation)



Rough estimation of channel insertion loss

- 25G

  See "Tanaka_3ca_1_0524.pdf" for 25G DML in detail

  - ✓ Use of uncooled DML may need FEC with higher coding gain than RS (255, 223), we need more study on APD receiver sensitivity with DML transmitter.
  - ✓ SOA integrated EML + APD can achieve 29dB channel insertion loss

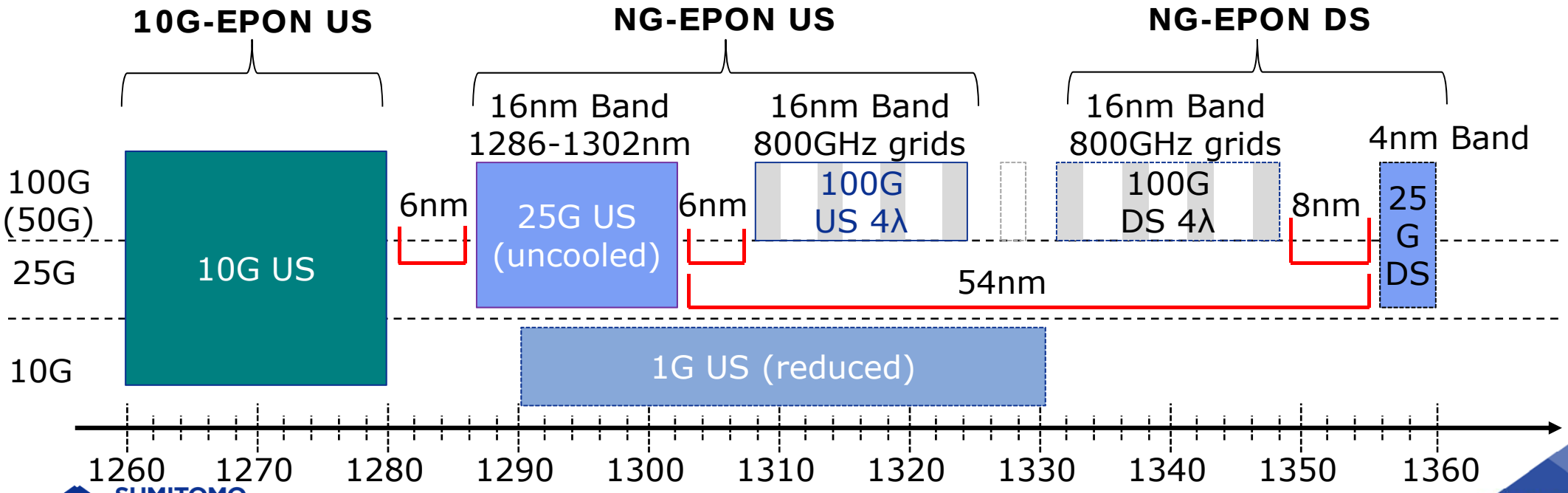
- 100G
  - ✓ 29dB channel insertion loss is doable with a help of SOA receiver.

Parameter	Optics Type	25G	100G	Notes
(1) Tx output power min. [dBm]	Uncooled DML Cooled DML SOA-EML	+6.5 (*) +7 to +7.5 (*) +7.5 to +8		ER>6dB ER>6dB ER>8dB
(2) Rx sensitivity max. at BER=10^{-3} [dBm]	APD SOA+PINPD	-23 (need study) -24 -27 (**)		ER=6dB ER=8dB ER=8dB, 2nm bandwidth
(3) Transmitter and Dispersion Penalty [dB]	DML SOA-EML	2.0 1.5		1280-1310nm 1260-1360nm
(4) 4λ WDM loss [dB]		NA	4 (***)	Include Tx and Rx
Channel insertion Loss [dB]		(1)-(2)-(3)-(4)		

(*) Higher coupling efficiency optical system
(**) Estimated from 100GBASE-ER4 specification, -21.4dBm (OMA) at BER=10^{-12}
(***) Thin film filter type

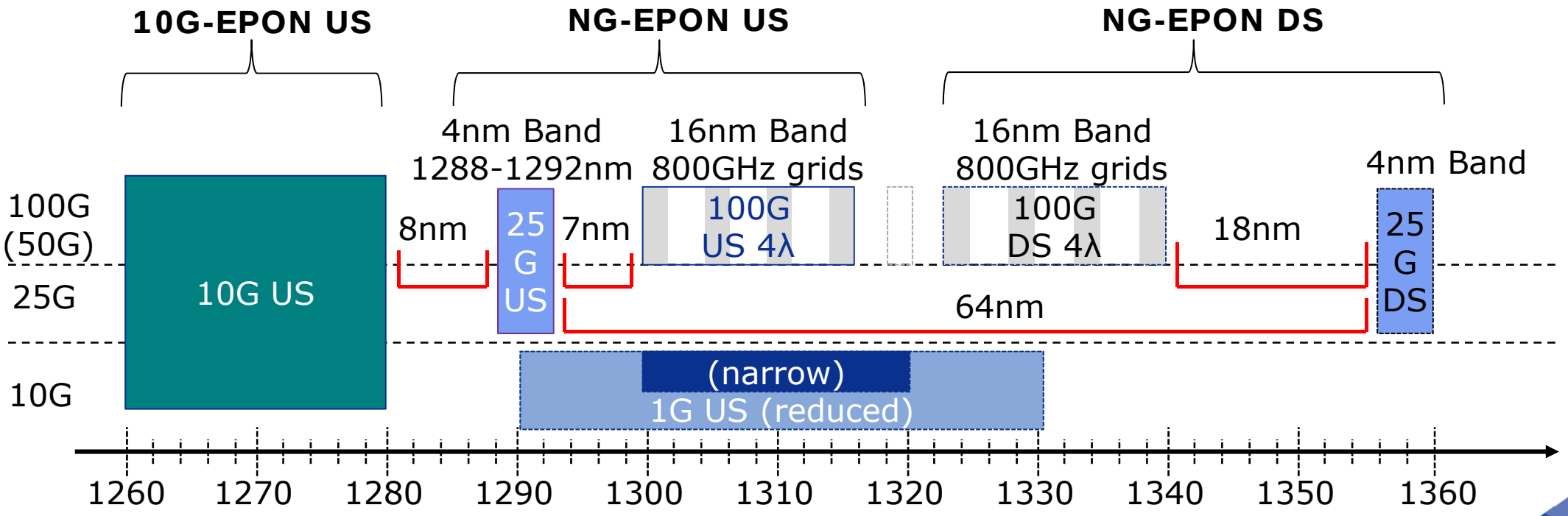
Wavelength allocation in O-band, example 1

- Allocation example 1: 25G US use uncooled Tx
  - ✓ 25G; 16nm bandwidth for US
    - Keep possibility of adopting economical uncooled Tx for 25G ONU
    - Need collimated light coupling Bi-D for 25G ONU to filter 100G DS
  - ✓ 100G; 800GHz grid LAN-WDM
    - Keep opportunity for 4λ integrated Optical Sub-Assembly (OSA)
    - Realize high Rx sensitivity by using SOA pre-amplifier
    - Enough margin for wavelength deviation caused by burst mode operation of Tx



Wavelength allocation in O-band, example 2

- Allocation example 2: 25G use cooled Tx
  - ✓ 25G; 4nm bandwidth with proper guard band
    - Higher cost than uncooled, but lower cost than 800GHz grid LAN-WDM
    - Lower cost non-collimated light coupling Bi-D can be adoptable in this example
  - ✓ 100G; 800GHz grid LAN-WDM



Summary

- 29dB channel insertion loss; Need high power and low TDP transmitter
  - ✓ SOA integrated EML; Good candidate, as presented in previous meeting
  - ✓ Uncooled DML; On the border line
    - Tx output power can be improved by Bi-D light coupling structure
    - Need more study on APD receiver sensitivity when DML transmitter is used
- Allocation in O-band
  - ✓ 100G and 25G (dedicated wavelength lanes) in O-band is doable
  - ✓ Examples
    - [Example 1] 25G uncooled Tx
    - [Example 2] 25G cooled Tx

Thank you