SUMITOMO ELECTRIC
Device Innovations USA

MOPA
Mobile Optical Pluggables Alliance

https://mopa-alliance.org

Aligning MOPA Blueprints with Industry Standards--UPDATE

Kenneth Jackson (Sumitomo Electric)

October 1, 2023

Introduction & Background

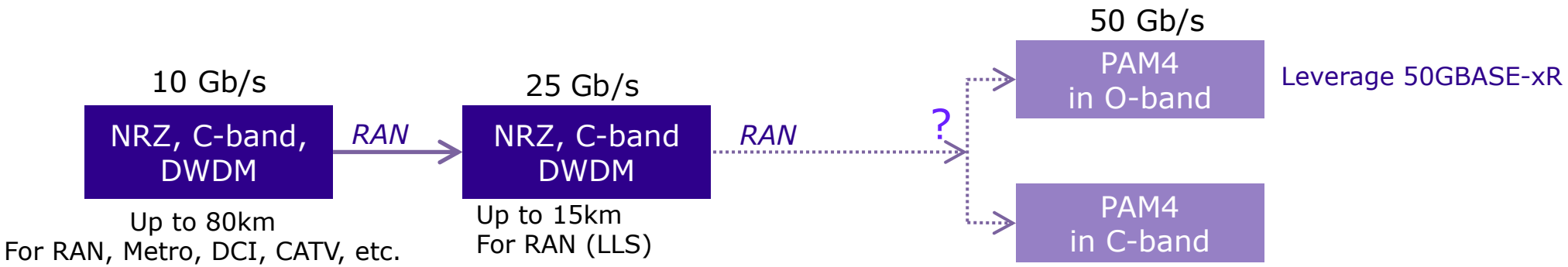
- **5G mobile systems (and soon 6G)** require significant growth in network capability resulting in an urgent and critical need for high-capacity, cost-effective *optical solutions*.

➔ The purpose of MOPA is to form an improved common understanding by defining *blueprints*, or network solution descriptions which document a use-case utilizing optical pluggables and passive optical components including high-level requirements.

- Prior releases of the MOPA **whitepaper** identified a number of industry standards that can be used to help specify the various optical transceivers used in the **nineteen** different blueprints.
  - Leveraging transceiver types from other high-volume applications (e.g. data center) can help drive lower costs and help focus the market on fewer variants.

➔ What's Next? xWDM variants for LLS (fronthaul) applications can be used to increase network capacity, provide greater flexibility and make efficient use of fiber resources. This will be a key improvement for 5 & 6G mobile network upgrades.

10 & 25Gb/s DWDM Solutions



Pluggables vs. Blueprints	10G-10km-*-C-6-2-SFP+	10G-15km-C-D-48-2-SFP+	25G-15km-C-D-48-2-SFP28
8.3.2	o		
8.3.3		o	o
8.3.4		o	o
8.3.5		o	o
9.2.4		o	o
9.2.8		o	o

- 10Gb/s solutions have been shipping for many years
  - Fixed WDM is mature & cost effective
  - Tunable (self-tuning) are available
- 25Gb/s standards are in-progress
  - Fixed & tunable are ramping
  - ITU-T 698.1 & 698.5 *(as starting points)*

Wavelength Options for DWDM 50 Gb/s Solutions

	Fiber Attenuation	Connectors Insertion Loss	Maintenance Margin	Mux/DeMux Insertion Loss	Total Loss budget
C-band DWDM 48ch	3.8 dB *	2 dB *	1 dB *	9 dB (2 x 4.5 dB)	15.8 dB
O-band DWDM 48ch	6.0 dB *	2 dB *	1 dB *	9 dB (2 x 4.5 dB)	18.0 dB

*Table ANA.1: Preliminary Loss budget estimations for C-band DWDM and O-band DWDM. * Using the values of Table 4 in Section 6.9.*

Wavelength Tradeoffs for 50 Gb/s Solutions

	Distance ***15km for LLS***	Module FF ***SFPx preferred***	Module Power ***<2.5W target***	Scalable to higher data-rates	Module Complexity	Note
PAM4 in O-band	**Possible 18dB @66ps/nm**	SFP56	2.5W for fixed λ sol'n (Tunable solution may be around 3.0W)	Low CD penalty w/ λ range close to λo (risk for FWM*)	Low	**Shortest time-to-market**, but **O-band DWDM grid not yet defined.**
PAM4 in C-band	**Impossible to achieve 15km**	SFP56		Impossible	Low	
PAM4 in C-band *(with ext. DCF)*	Should be OK	SFP56		?	Low/ Mid	**DCF not preferred by end-users.**
PAM4 in C-band *(with EDC)*	Unknown	SFP56 (?)	Unknown (but larger than options above)	?	Mid	**Needs continuing investigation.**

DCF = Dispersion compensation fiber
EDC = Electronic dispersion compensation

** See Whitepaper Annex A, Section 2 for FWM analysis*

- **C-band (1550nm wavelength) exhibits higher chromatic dispersion (CD) than O-band (1310nm)**
  - Optical and/or electrical domain equalization can be employed to remove the CD impairment but at the expense of higher complexity, higher power dissipation and ultimately higher costs

➔ **For this reason, O-band is considered. However, operating near the zero-dispersion wavelength (ZDW) of the fiber, can result in non-linear Four-Wave-Mixing (FWM) which can limit the maximum allowed optical power levels which in turn will limit the overall link budget that can be achieved.**

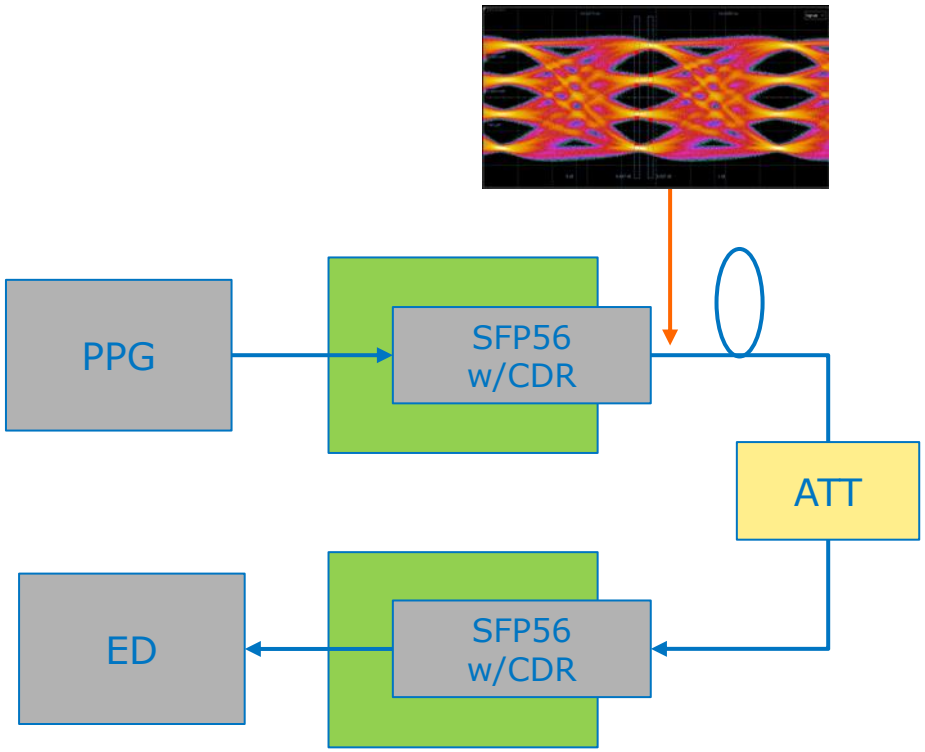
- **By utilizing a wavelength grid that is shifted from the fiber ZDW, one can trade-off dispersion penalties with FWM penalties.**

Preliminary 50Gb/s DWDM Blueprint

Typical use cases (Blueprints)	15 km RU-DU, passive DWDM over a single fiber Blueprint (Section 8.3.3) 15 km RU-DU, passive DWDM bus over a single fiber Blueprint (Section 8.3.4) 15 km RU-DU, semi-active DWDM bus over a single fiber Blueprint (Section 8.3.5)
Distance	Min 0 km; **Max: 15 km**
Channel Insertion Loss	**18 dB** (in O-band)
Chromatic Dispersion	< 65 ps/nm @ 1350nm
Mode, Nr ch., Wavelengths	Dual fiber pluggables, single fiber trunk: 48 wavelengths @ 100 GHz spacing, 1320 – 1350nm
Temp. Range/Class	I-temp
Lifespan	15 years
Data rates	**50 Gb/s**
Formfactor	SFP56
FEC, Mod format	yes, PAM4
Power Class	PC4 / 2.5 W preferred (3.0W appears to be more reasonable target for tunable solutions)
Pluggables codes	**50G-15Km-O-D-48-2-SFP56**
Key technologies	Low-cost 50Gb/s EML DWDM without wavelength lockers, APD. Athermal AWG or TFF filters
Standards	No

Feasibility of O-band for 50Gb/s DWDM Blueprint

Test Setup



- DUT

  Following key components are incorporated in SFP56 FF;

  - EML:
  - APD:

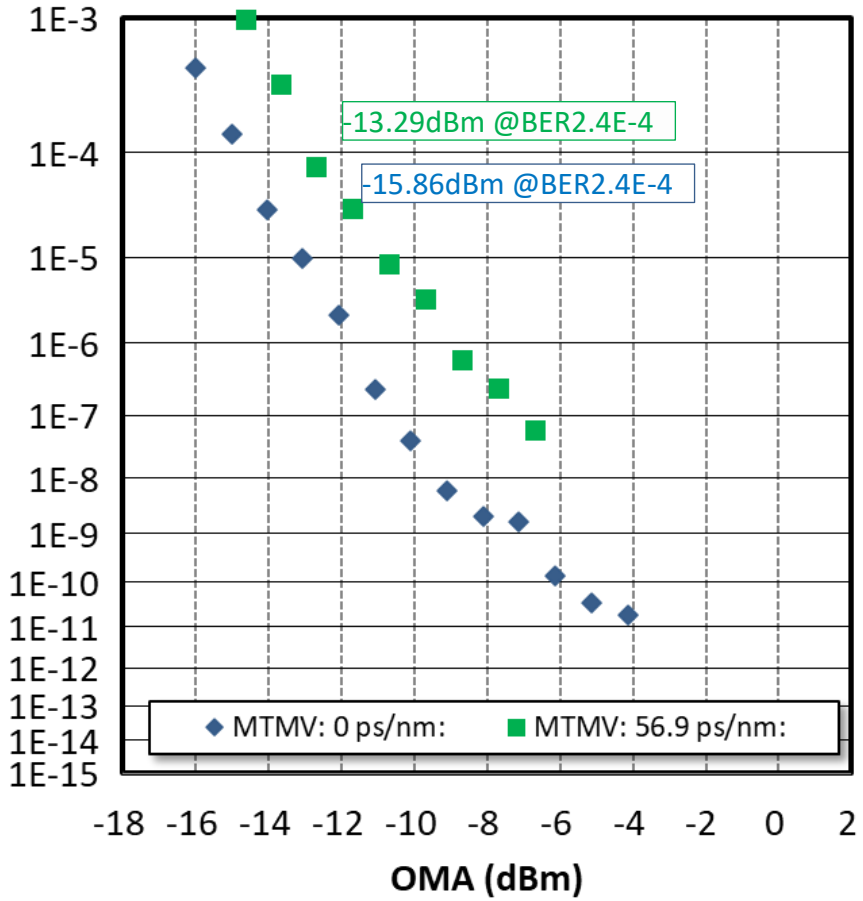
    SUMITOMO ELECTRIC

  - PAM4 CDR: SEMTECH

- Test Conditions
  - 53.135 Gb/s
  - PRBS15Q for Tx Eye, PRBS31Q for BER
  - B2B (0ps/nm) and 56.9ps/nm.
  - 3.3V, Room Temp
    - Module Power consumption: 1.8W

Feasibility of O-band for 50Gb/s DWDM Blueprint (con't)

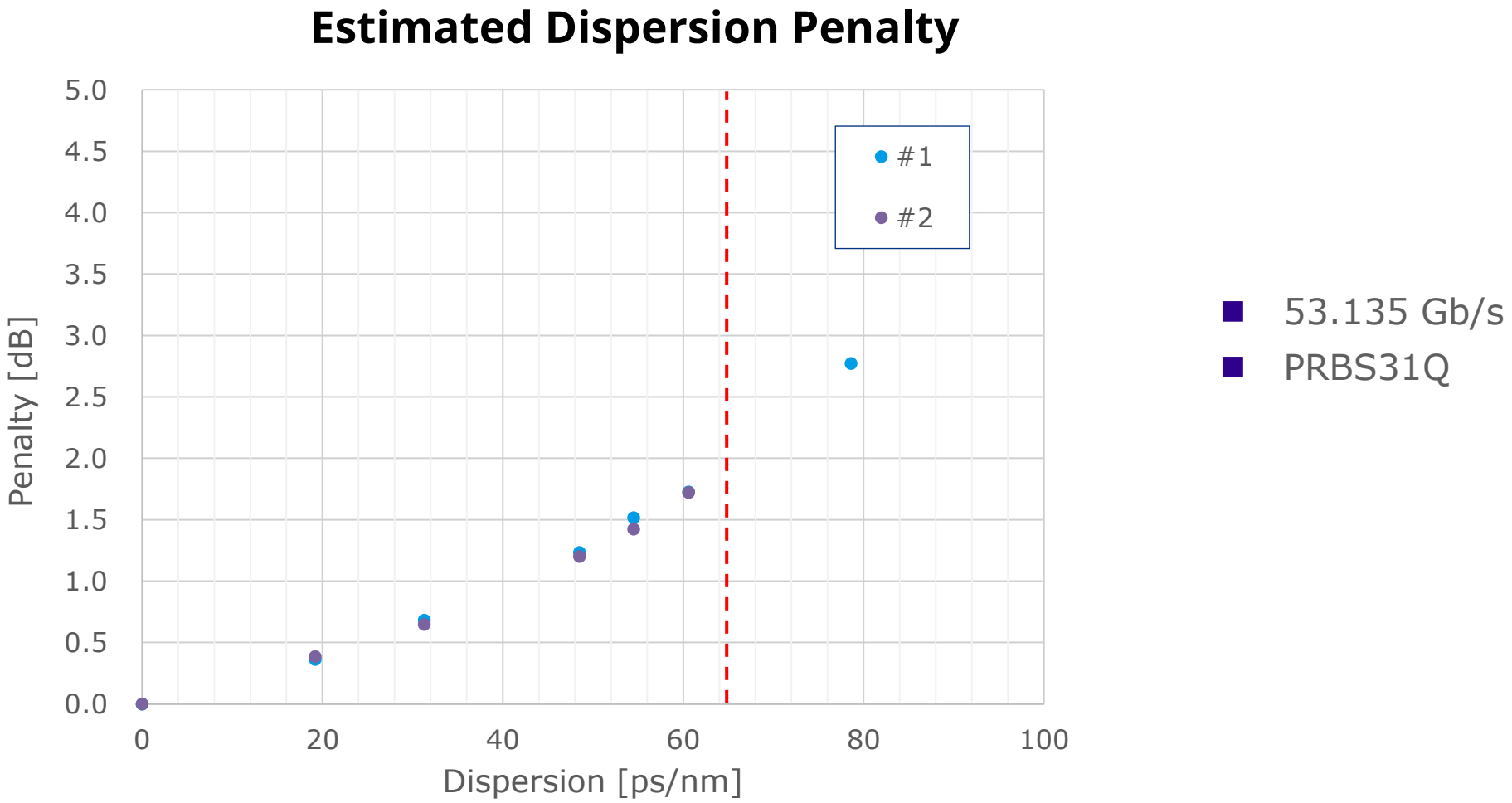
Test Results of Key Parameters



Item	Unit	Test data
Average Power	dBm	4.9
Extinction Ratio	dB	7.5
Tx OMA	**dBm**	**6.4**
TECQ	dB	1.2
Rx Sensitivity in OMA @0ps/nm	**dBm**	**-15.9**
Rx Sensitivity in OMA @56.9ps/nm	dBm	-13.3
Total Loss Budget	**dB**	**22.3**
Insertion Loss budget	**dB**	**18.0**
Allocation for Penalties	**dB**	**4.3**

- 53.135 Gb/s
- PRBS15Q for Tx Eye, PRBS31Q for BER

Feasibility of O-band for 50Gb/s DWDM Blueprint (con't)



➔ Dispersion penalty at 65ps/nm is ~2dB

Summary

- **50Gb/s WDM Blueprints for LLS (fronthaul) are required for next generation 5G/6G networks**
  - Leveraging existing 50Gb/s, PAM4 technologies may be the best choice
    - Time-to-market
    - Lowest cost (leveraging high volumes)
  - However, wavelength grid needs to be selected carefully ➔ trade-off between CD and FWM penalties
  - 1320-1350nm band with 100GHz ch spacing may be feasible as shown by exp't results

➔ Standards development organizations (SDOs) to be consulted regarding this direction.

SUMITOMO ELECTRIC
Device Innovations USA

Thank You!

MOPA
Mobile Optical Pluggables Alliance