50G single wavelength PON analysis and comparison

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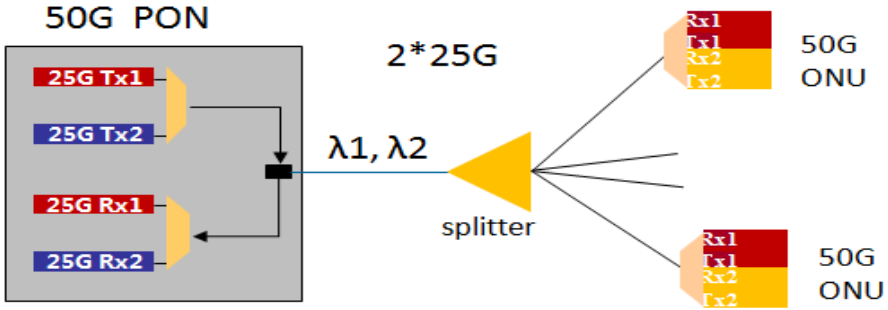
Background

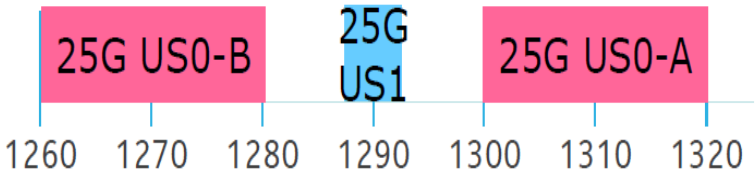
- In 2017 July Berlin meeting, It was agreed that the task force should analyze and compare different solutions for 50G PON

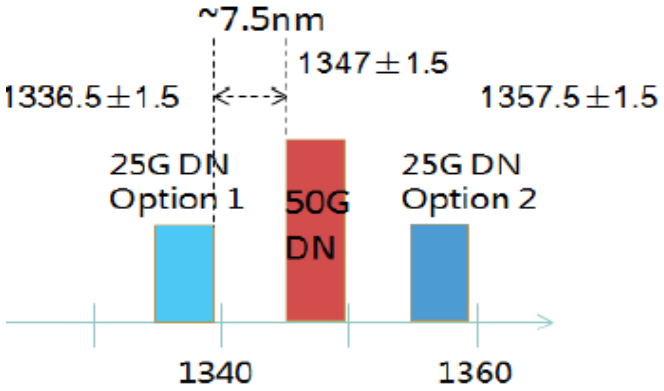
Motion #6
The Task Force should analyze and compare the following solutions for 50G PON and choose the best one for 50G EPON: 1) Single wavelength TDM-PON with 50Gb/s line rate, 2) Two-wavelength TDM/WDM-PON with 25Gb/s line rate per lane. The Task Force calls for contributions on these topics. Moved: Dekun Liu Second: Liquan Yuan For: 22 Against: 0 Abstain: 4 Procedural (> 50%) Motion Passed

- This contribution analyzes the different solutions to 50G PON and proposes the specs for 50G single wavelength PON

2*25G PON







➢2*25G PON system's power budget is 2-dB less than 25G-PON's

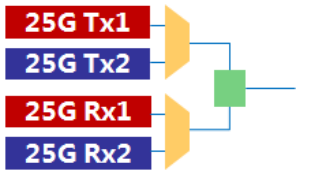
- ✓MUX/DEMUX's IL is 1-dB respectively.

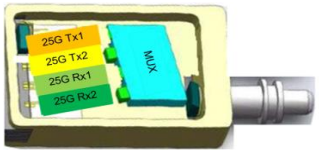
➢Pros:

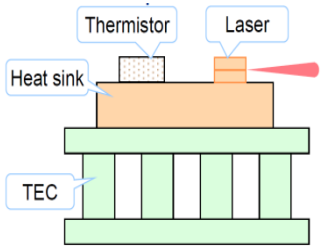
- ✓25G photoelectric devices are available.
- ✓Based on NRZ modulation, modulation penalty and technical complexity are relatively low.

➢Cons:

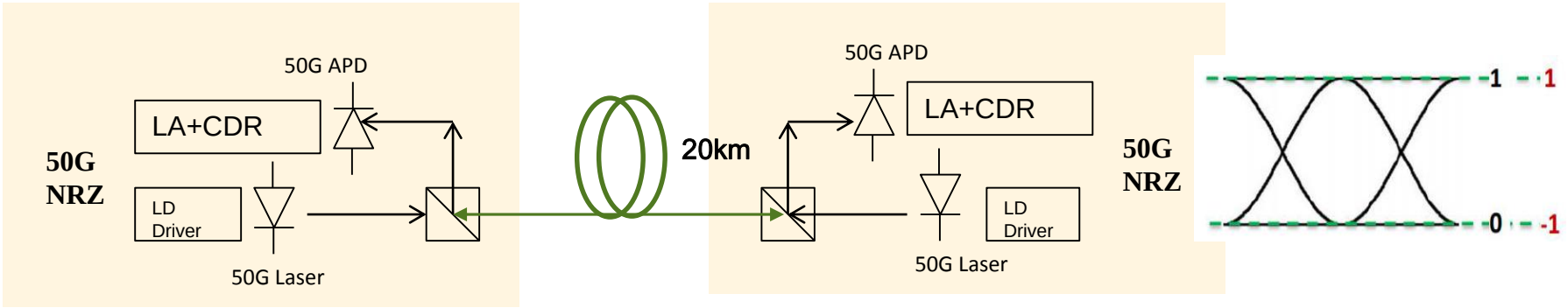
- ✓50G ONUs need to be cooled
- ✓More wavelength source is need which increase both 25G and 50G cost
- ✓Two lasers and APDs are needed in each side, package cost will be high.
- ✓Cost per Gbit is higher than 25G PON, application scenario is vague







50G PON NRZ



40G~50G Laser provider

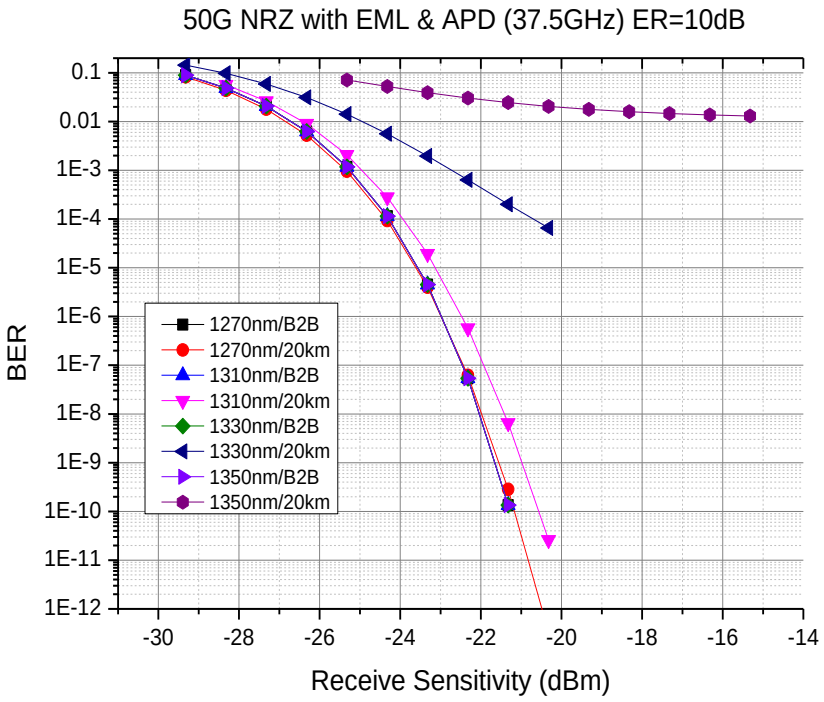
Vendor	N	N	H	P	I	M	S
3-dB bandwidth	32GHz(43G EML)	50GHz(56G EML)	31~36GHz(50G EML)	20GHz(25G EML)	20GHz(25G EML)	TBD(43G EML)	TBD(43G EML)
Extinction Ratio	10dB	--	>7dB	--	--	>8.5dB	>8.2dB
Output Power	>5dBm	--	8dBm(with SOA)	--	6dBm	1.5dBm	0~4dBm

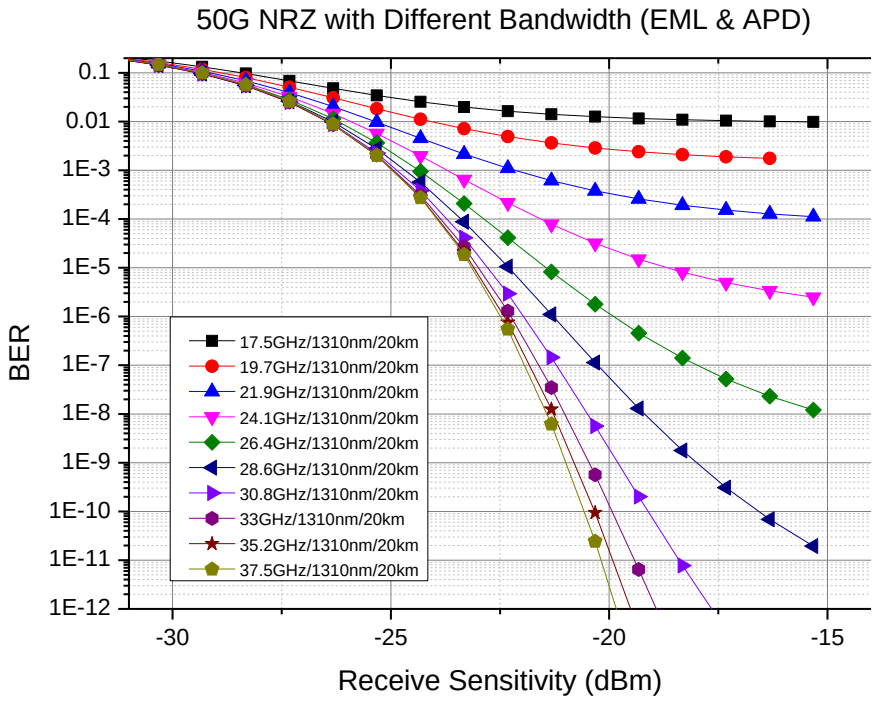
40G~50G electrical devices provider

Limiting Amplifier	CDR	TIA	SERDES	Laser Driver	FPC interface
Gigpeak	**Semtech, Mindspeed**	**TriQuint**	**Credo**	**TriQuint**	**Mitsubishi Electric**

50G PON NRZ

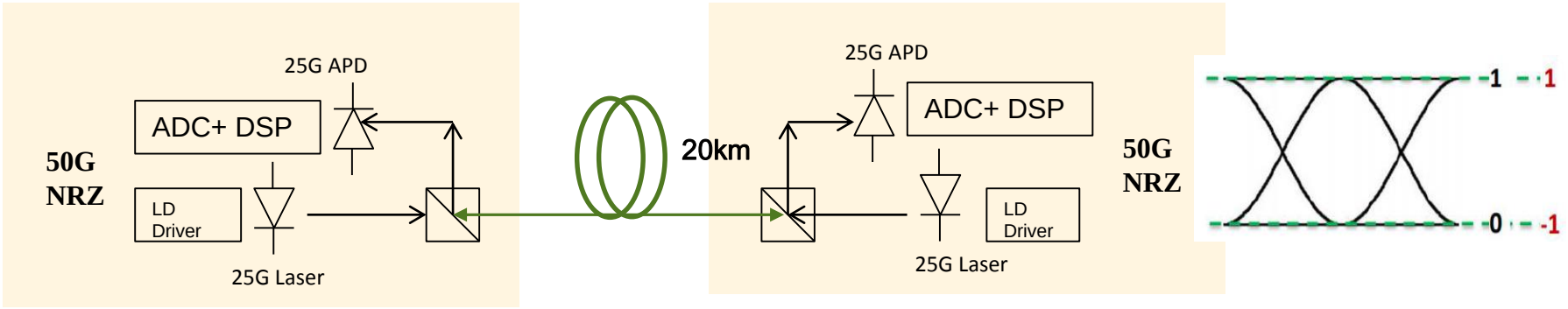
VPI simulation result





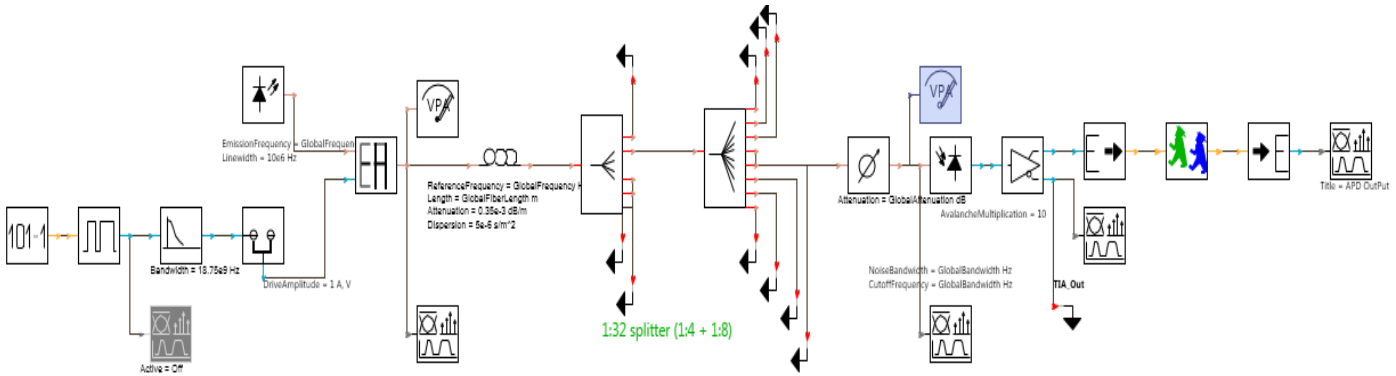
- 1310nm and O- band transmission are supported using 50G optics, -25.3dBm@BER=1e-3 can be obtained according to the simulation.
- O+ band transmission is very hard as 50G-NRZ is very sensitive to dispersion.
- At 1310nm, the 3-dB bandwidth of EML and APD should be ~25GHz based on simulation.
  - Cons
    - 50G optics are needed, cost is high
    - 50G-APD is not available so far

50G PON based on 25G optics with assistant of DSP



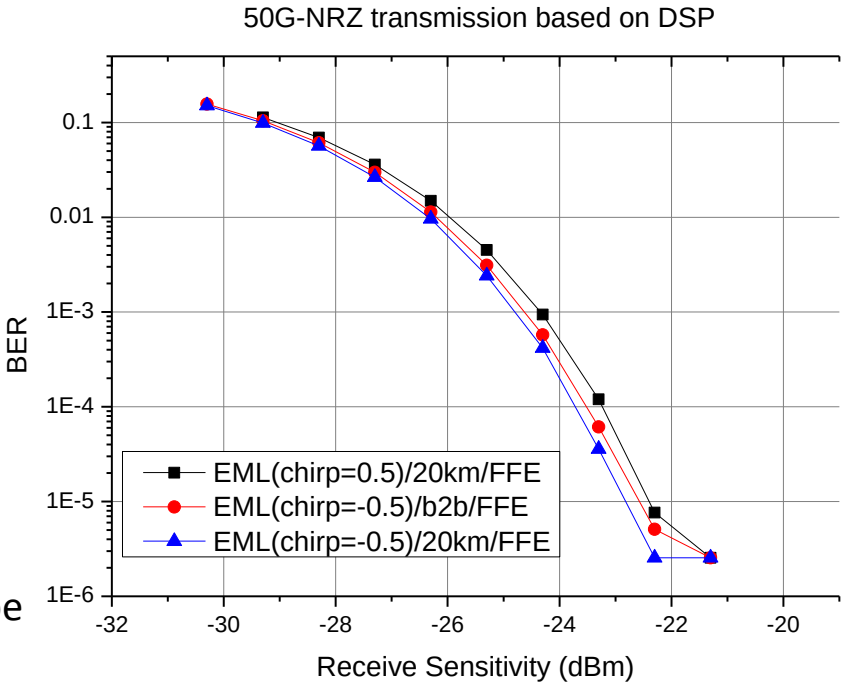
- DSP Compensation
  - ✓Clock and data recovery
  - ✓Digital compensation
    - •FFE: Feed forward equalizer
    - •DFE: Decision Feedback Equalizer
    - •MLSE: Maximum likelihood sequence estimation

50G PON based on DSP: Simulation



simulation setup

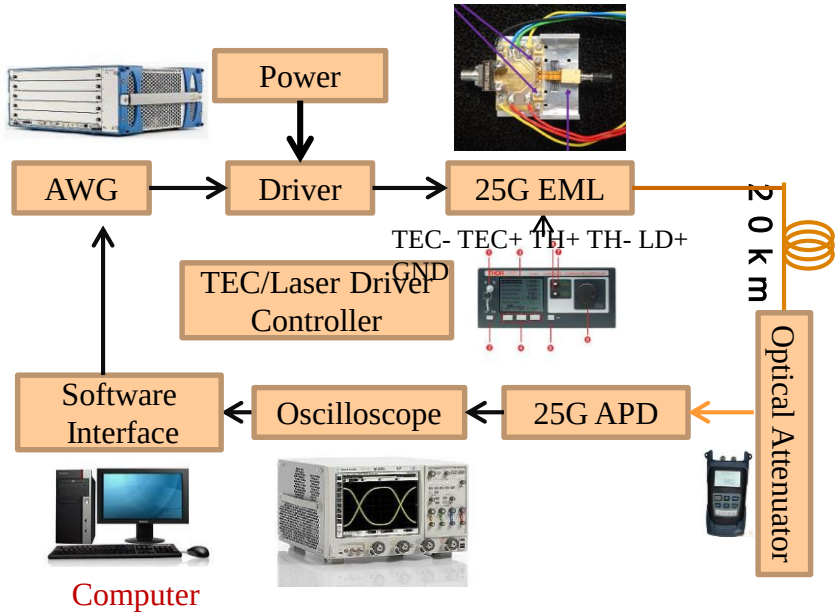
50G-NRZ transmission		
25G-EML	3-dB bandwidth	18.75GHz
	ER	~5dB
	Output Power	4dBm
25G-APD	3-dB bandwidth	18.75GHz
1310nm		
DSP compensation		



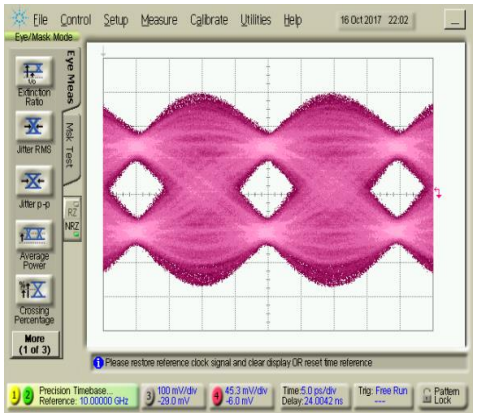
➢-25dBm@BER=1e-3 after 20-km transmission can be got just using FFE when EML chirp factor is -0.5

➢-24.4dBm@BER=1e-3 after 20-km transmission can be got just using FFE when EML chirp factor is 0.5

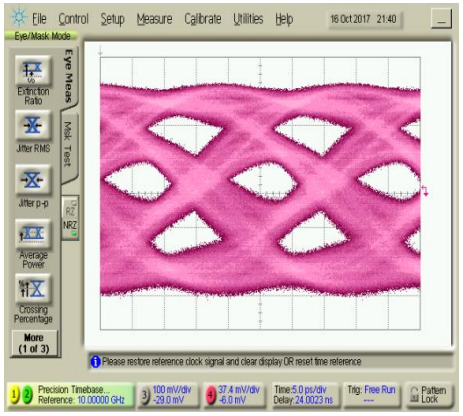
50G PON based on DSP: Experiment



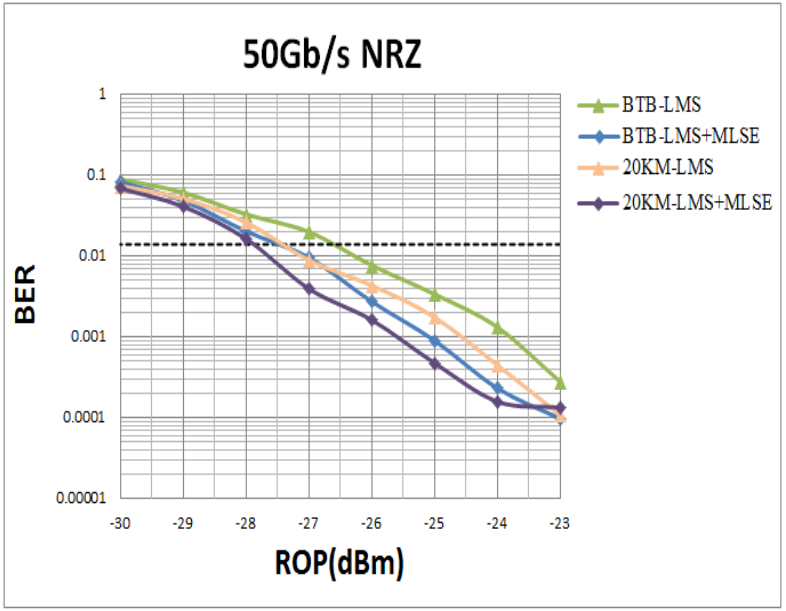
Electronic eye diagram



Optical eye diagram

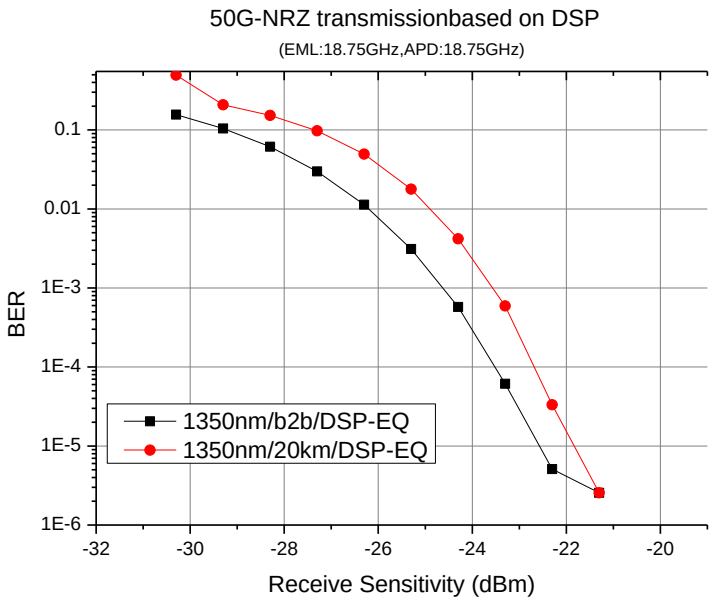


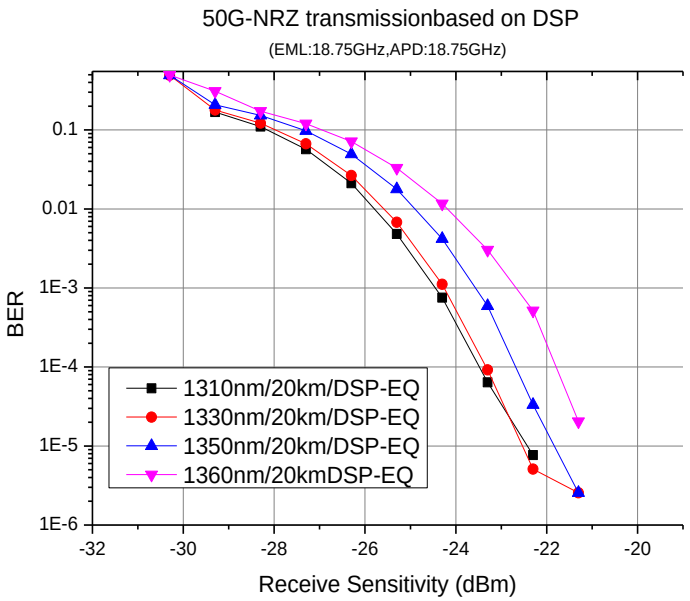
50G-NRZ based on 25G optics with DSP	
25G-EML	**Vendor M: +5dBm**
25G APD	**Vendor S**
1310nm	
DSP compensation	

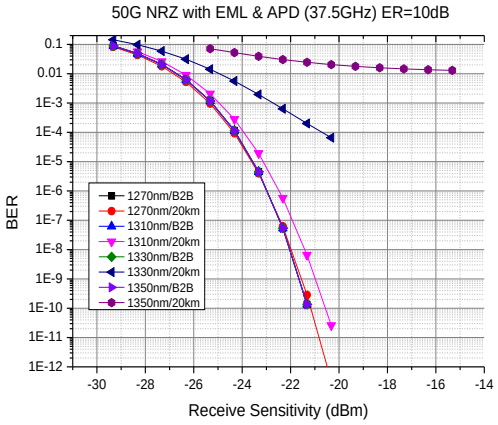


- -27.5dBm@BER=1.4e-2 after 20-km with FFE only
- -24.5dBm@BER=1e-3 after 20-km with FFE only

Advantage of 50G PON based on DSP

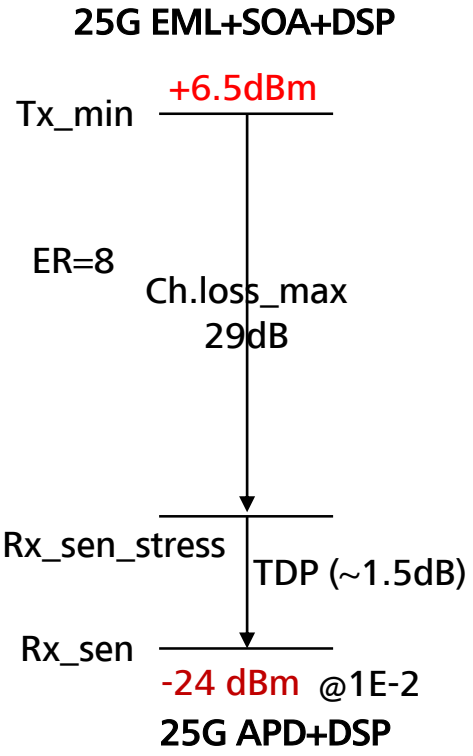


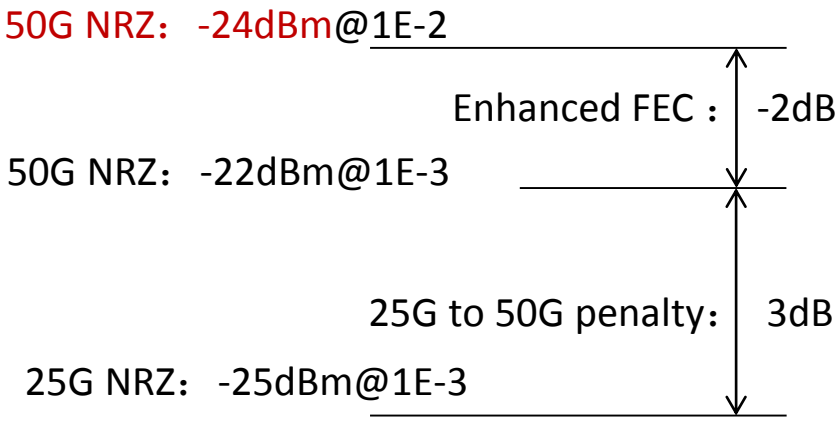




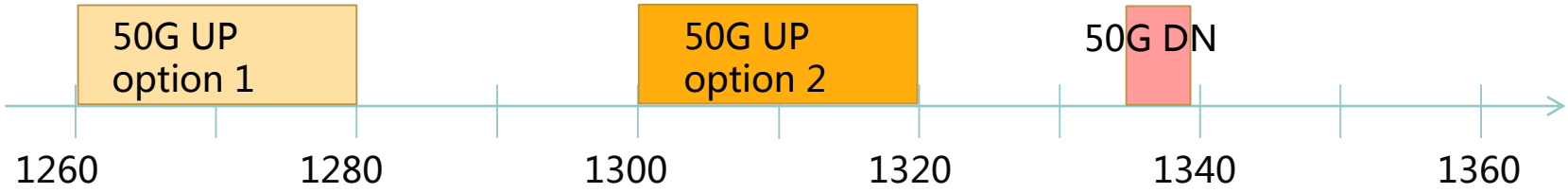
- O+ band is supported by DSP-EQ of 50G-NRZ transmission.
- Dispersion penalty is about 1-dB in 1350nm

50G PON NRZ power budget and wavelength plan

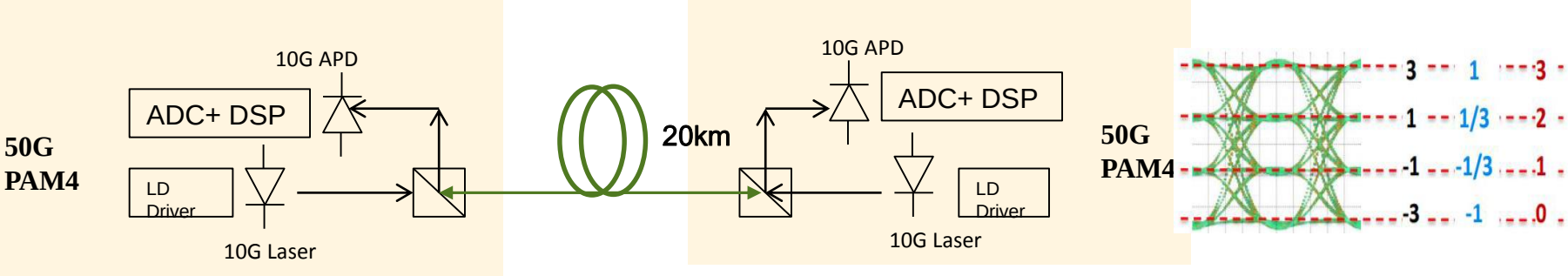


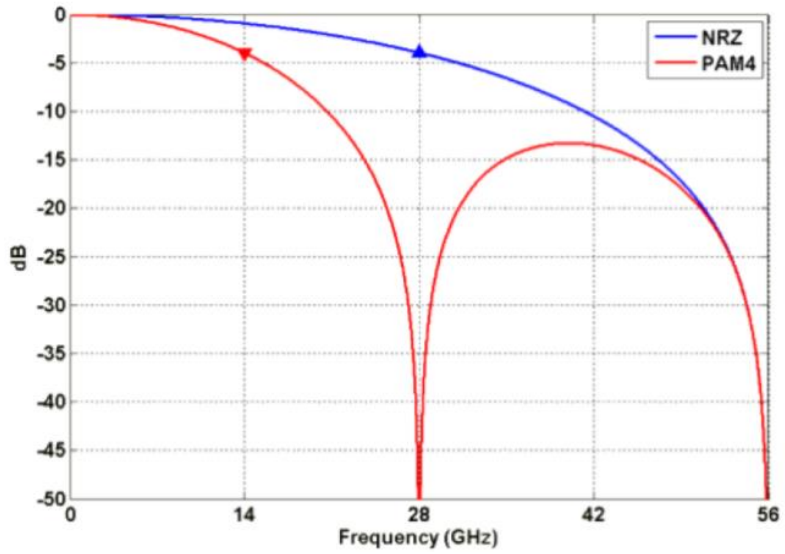


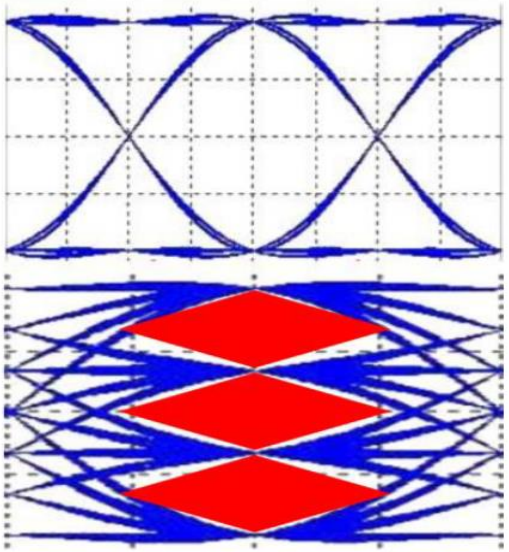
Note: assume some base line improvement on 25G APD sensitivity more details see liu_3ca_1_1117 and guo_3ca_1_0917



50G PON based on PAM4







50G PON PAM4 based on 25G optics

50G PAM4：-21.5dBm @1E-2

50G PAM4：-19.5dBm @1E-3

25G NRZ：-25dBm @1E-3

Enhanced FEC：-2dB

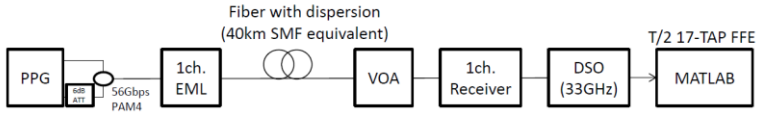
PAM4 penalty：5.5dB

Note: assume some base line improvement on 25G APD more details see liu_3ca_1_1117 and guo_3ca_1_0917

sone_ecdc_01b_0516

Evaluation overview and summary of results

1ch. 56Gbps PAM4 optical transmission experiments using different EMLs and an APD/PIN-PD receiver. Dispersion of fiber is set assuming worst-case dispersion for LAN-WDM transmission over 40km SMF.

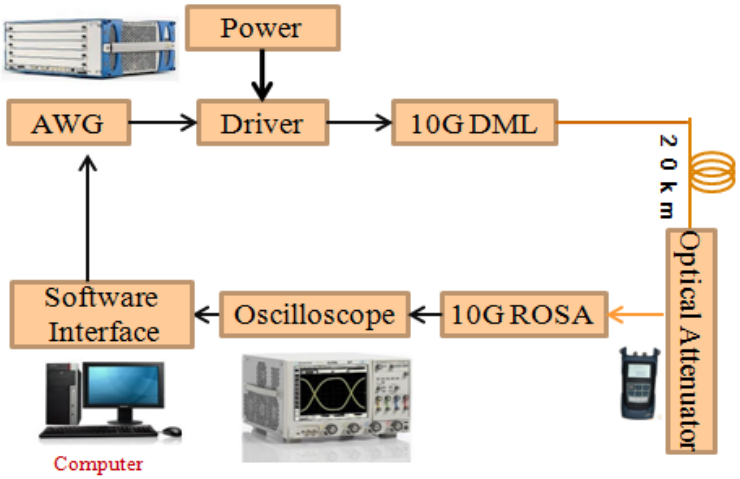


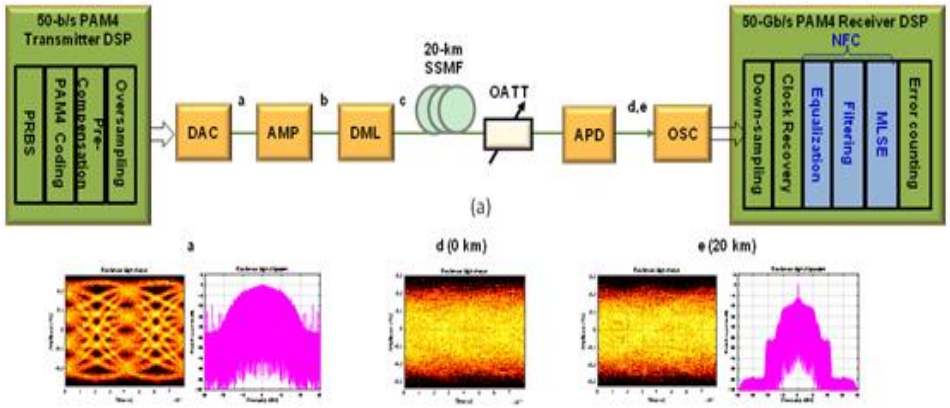
Tx	Fiber dispersion [ps/nm]	Rx	KP4 (limit=2E-4) Min. receiver sensitivity*1 [dBm]	KP4 (limit=2E-4) CD Penalty [dB]	Stronger FEC(limit=1E-3 *2) Min. receiver sensitivity*1 [dBm]	Stronger FEC(limit=1E-3 *2) CD Penalty [dB]
EML#1 ER=5.6[dB] 1304.3nm(L6)	-203	PIN-PD receiver	-18.6	~1.5	-19.4	~0.5
	0					
	+38					
EML#2 ER=5.8[dB] 1308.9nm(L7)	-203	APD receiver	-22.8	~1.5	-23.9	~0.5
	0					
	+38					

NTT

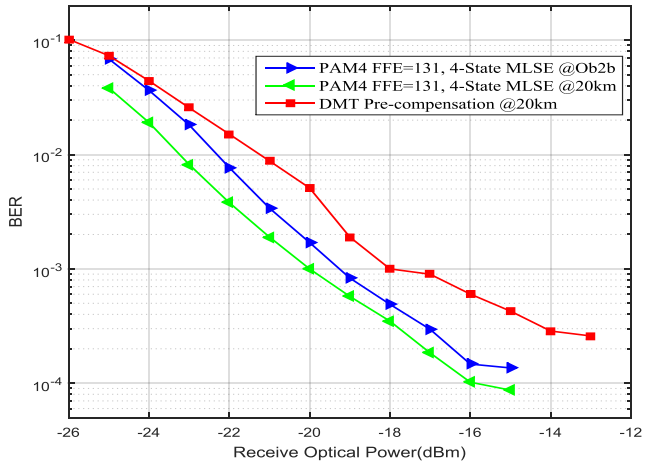
* 1 OMAinner, Without WDM-demux, value at zero ps/nm
* 2 tentative BER limit assuming possible FEC(s) stronger than KP4

50G PON based on PAM4 with 10G optics

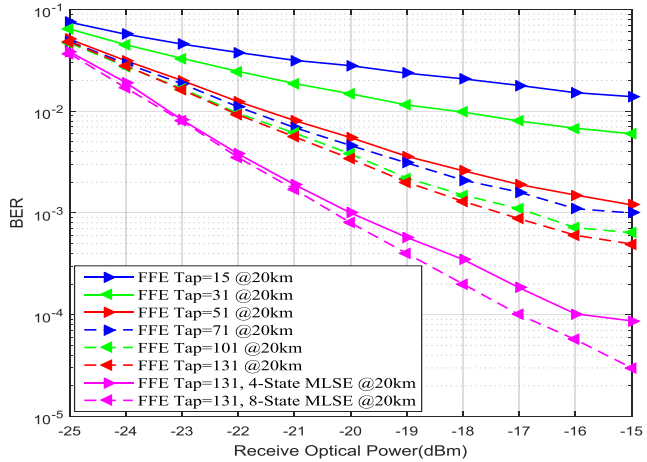




Measured BER performance of 50-Gb/s PAM4 based on 10G



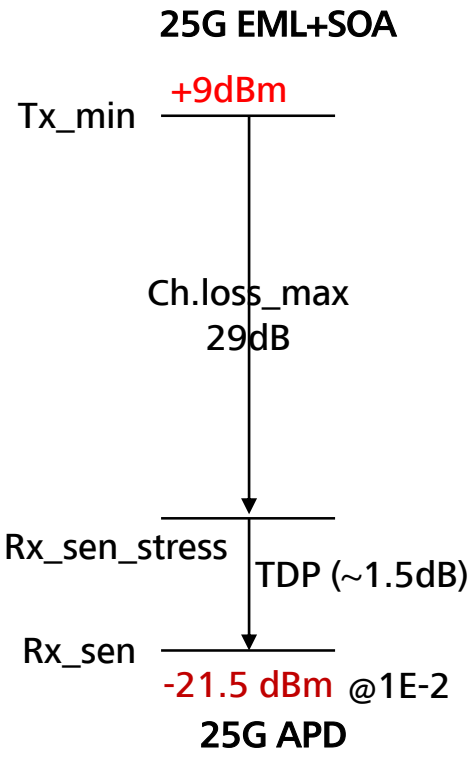
Measured BER performances of 50-Gb/s PAM4 for different



50G PAM4 based on 10G optics with FFE+MLSE after 20km

-20.7dBm@BER=1e-3, ~-23dBm@BER=1E-2

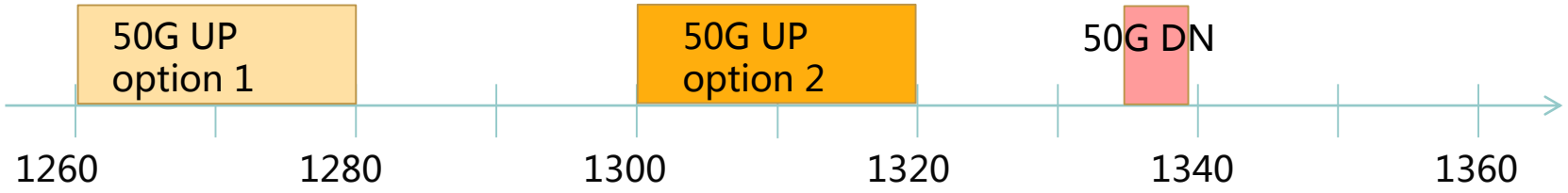
50G PON based on PAM4 power budget and wavelength plan



harstead_3ca_3_0917

AVPmin (dBm)	number	mean	σ
EML	6	4.6	0.7
EML+SOA	3	8.7	2.0
cooled DML	6	6.5	0.5

ER (dB)			
EML	6	7.5	0.8
EML+SOA	3	7.3	1.2



Cost comparison

solution	Key cost components		Total cost by weigh*
	OLT	ONUs	
1 *25G NRZ	one 25G EML+SOA* one 25G APD 25G EML driver+25G BTIA&BCDR	one 25G uncooled DML one 25G APD 25G LDD+25G TIA&CDR	1
2*25G	two 25G EML+SOA two 25G APD mux & demux Two 25G EML driver+two 25G BTIA&BCDR	two cooled 25G DML two 25G APD mux & demux Two 25G LDD+25G TIA&CDR	2.15
1*50G NRZ based on DSP	one 25G EML+SOA one 25G APD+pre-SOA 25G EML driver+25G TIA oDSP chip*	one uncooled 25G DML one 25G APD 25G LDD+25G TIA oDSP chip	1.2
1*50G based on PAM4	one 25G EML+enhanced SOA* one 25G APD+pre-SOA PAM4 driver+25G linear TIA PAM4 encoder and Decoder	one uncooled 25G DML one 25G APD PAM4 driver+25G linear TIA PAM4 encoder and Decoder	1.3

* Note:

- 25G OLT is assumed to need a common EML+SOA, while 50G based on PAM needs a special designed EML+SOA
- :the total cost by weigh assume the volume ratio of OLT : ONU = 1 : 20
- The cost of oDSP is estimated based on the experiments in page 8,including FEC, ~3.5*3.5mm^2 die size, 16nm ASIC technology (more reference in liu_3ca_4_1116)

Summary

- Several solutions of 50G PON are analyzed:
  - both 50G PON single wavelength based on NRZ+DSP and PAM4 are feasible to meet the 29dB power budget, with the assistance of DSP and/or booster amplifier.
- 1*50G has the following potential benefits over 2*25G :
  - Saving in wavelength resource
  - Simplicity in hardware and management
  - Cost-effectiveness
- Spec and wavelength plan shown in page 10 and page 14 are recommended as the starting point for 50G single wavelength PON analysis.

Thank you

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