Low cost 25G PAM-4 solution for Next Gen 100GE PMD

Xiaolu Song, Li Zeng, Kai Cui, Peter Stassar

Huawei Technologies Co., Ltd.

Next Gen 100Gb/s Ethernet Optics Group
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HUAWEI

List of Supporters

- Junjie Li, China Telecom
- Song Shang, Semtech
- *Frank Chang, Vitesse*
- Wenbin Jiang, Cosemi
- Wenyu Zhao, CATR MIIT
- Haiyi Zhang, CATR MIIT

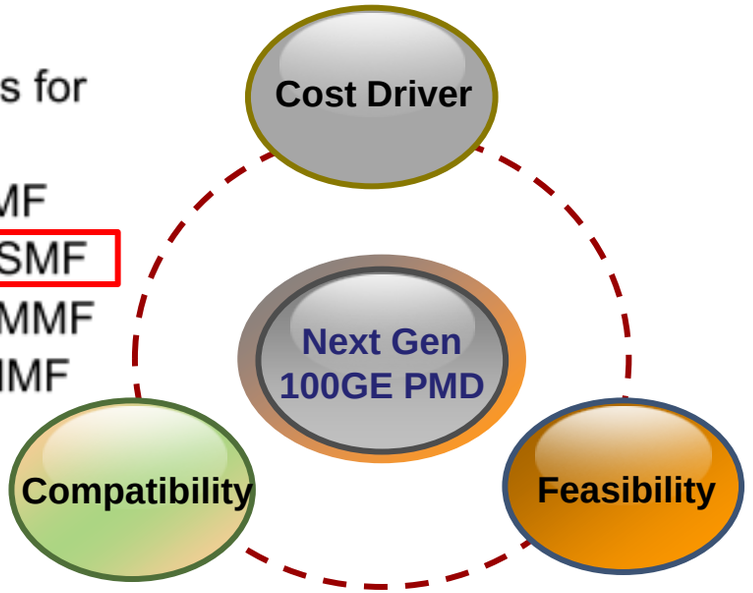
Outline

- Next Gen 100GE Optics Scenarios
- Proposal for Low Cost PAM-4 Solution
- Technical Feasibility and Simulation Verifications
- Scaling Factors & Cost Trend Expectation
- Summary

Next Generation 100GE Optics Scenarios

Currently Approved Objectives

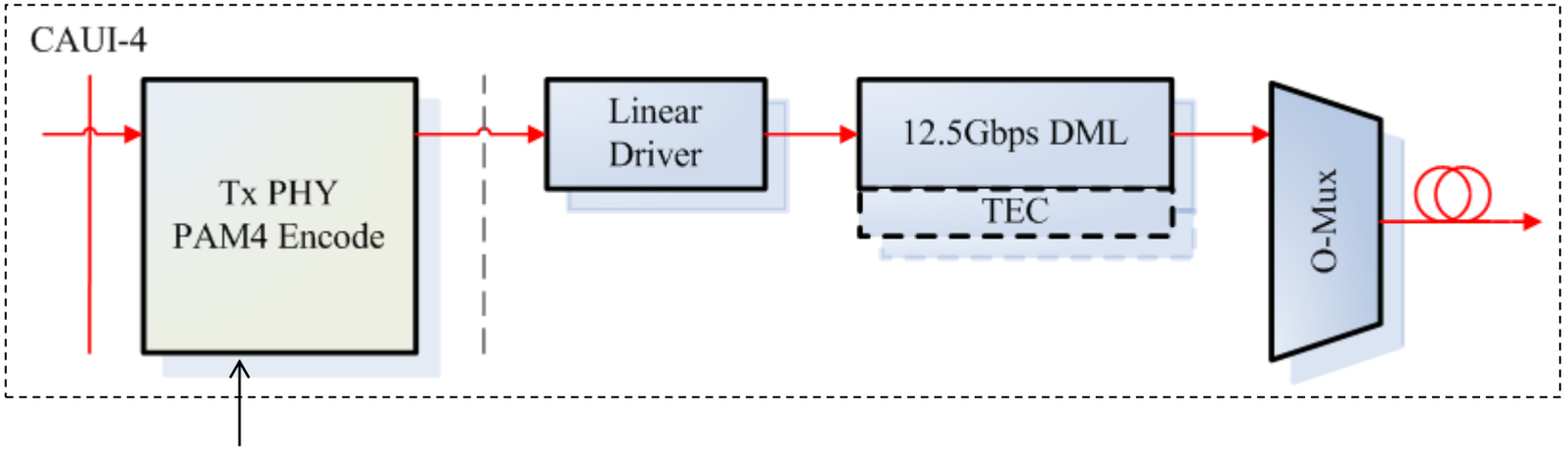
- Support full-duplex operation only
- Preserve the IEEE 802.3 / Ethernet frame format utilizing the IEEE 802.3 MAC
- Preserve minimum and maximum FrameSize of current IEEE 802.3 standard
- Support a BER better than or equal to 10^{-12} at the MAC/PLS service interface
- Provide appropriate support for OTN
- Define re-timed 4-lane 100G PMA to PMA electrical interfaces for chip to chip and chip to module applications
- Define a 40 Gb/s PHY for operation over at least 40 km of SMF
- Define a 100 Gb/s PHY for operation up to at least 500 m of SMF
- Define a 100 Gb/s PHY for operation up to at least 100 m of MMF
- Define a 100 Gb/s PHY for operation up to at least 20 m of MMF



Proposal for Low Cost PAM-4 Solution

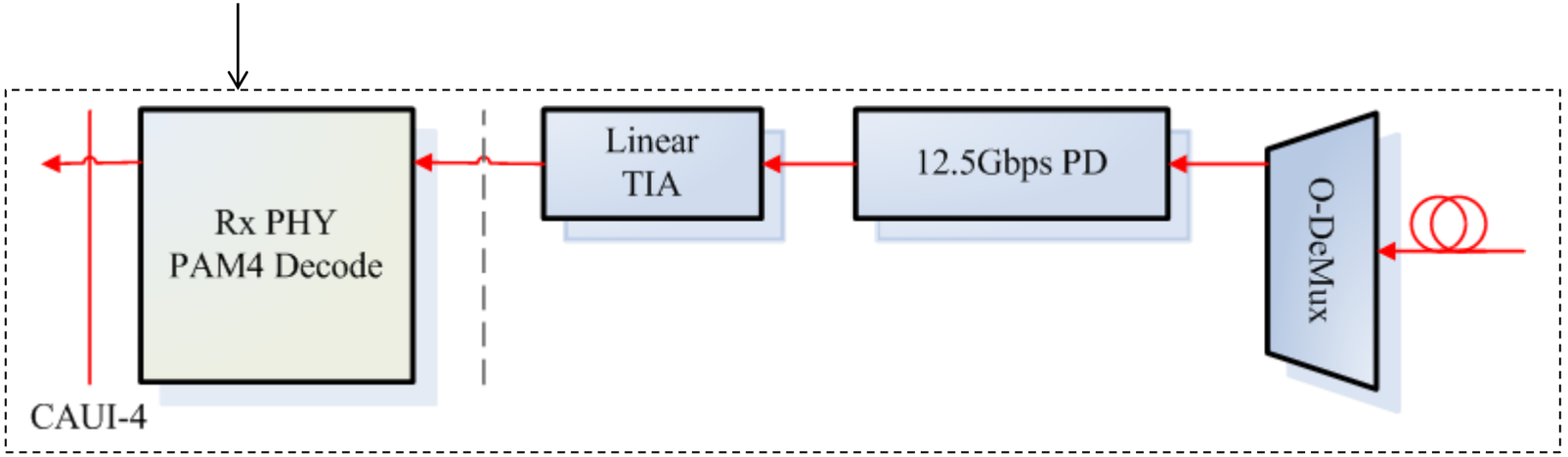
Relax of bandwidth requirements:

12.5GBaud DML, PIN-PD (low cost w/o external modulator)



Tx, 4x25Gbps PAM-4

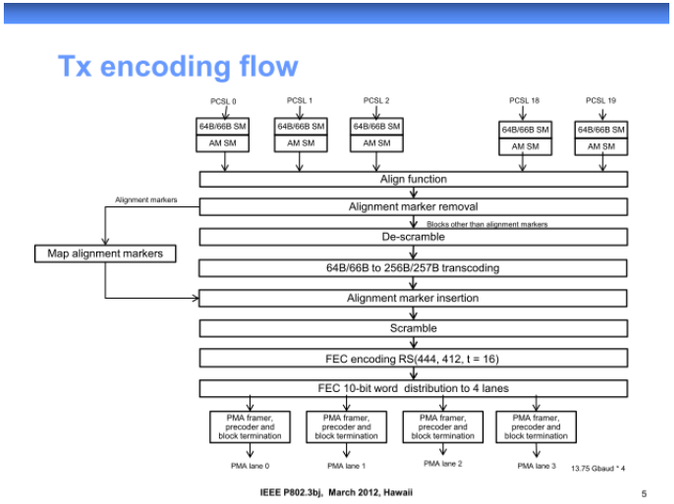
Feasibility demonstrated in 802.3bj regards PAM-4 PHY implementation

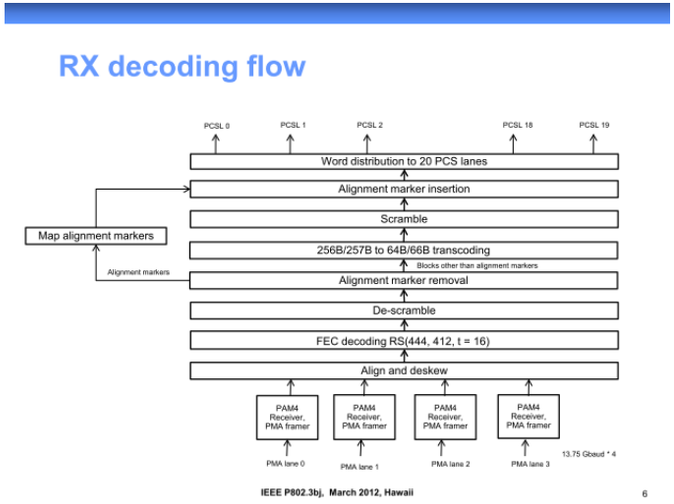


Rx, 4x25Gbps PAM-4

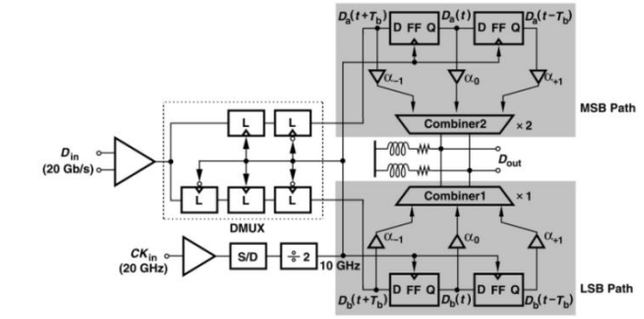
Technical Feasibility

IEEE 802.3bj: M. Brown, et al, brown_01_0312, 100G backplane PAM4 PHY.

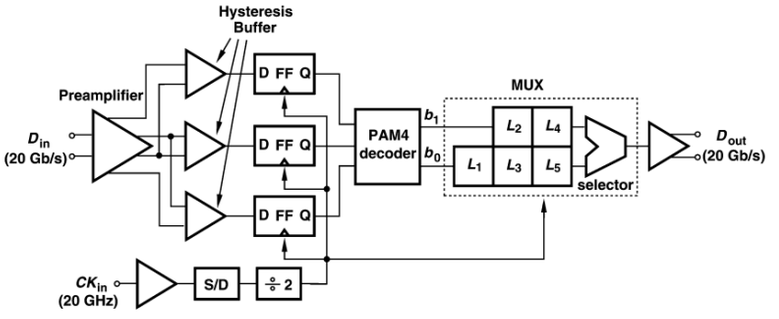




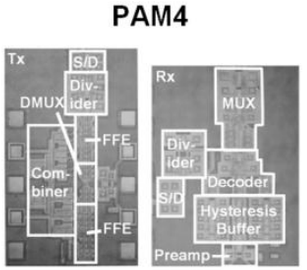
Research publications: Jri Lee, et al, IEEE JOURNAL OF SOLID-STATE CIRCUITS, Sep 2008, PAM-4 Tx/Rx.



PAM4 transmitter.



PAM4 receiver.



Tx	Rx
0.65 mm×0.30 mm	0.60 mm×0.40 mm

Simulation Verifications

Simulation Software: VPI Version 8.6

Tx

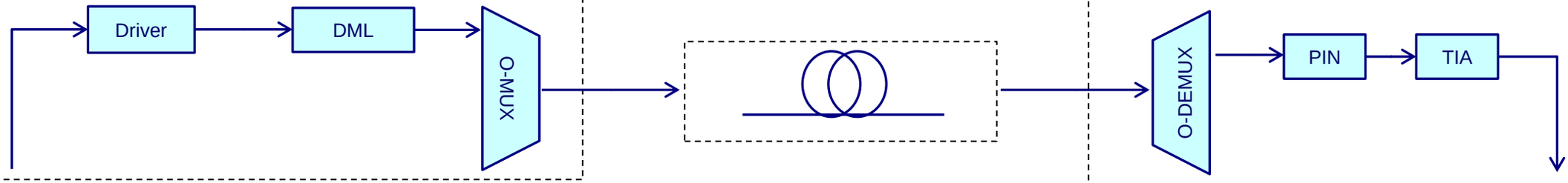
[1] Rate equation model for DML under a poor condition, factors including:

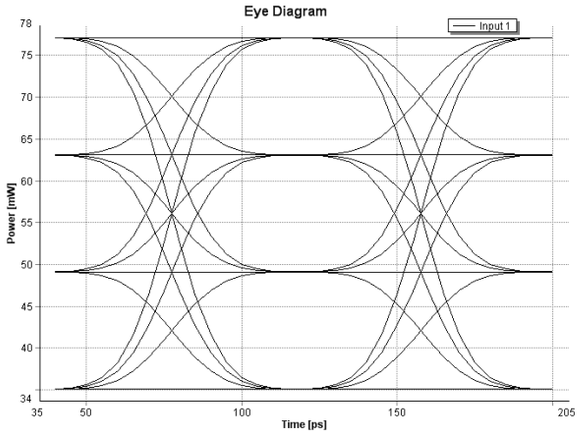
- ✓ **Frequency response 10.7GHz**
- ✓ **RIN = -138dB/Hz**
- ✓ **Chirp = 4**
- ✓ **Output ER = 4dB**

[2] Fiber attenuation loss (max) = 0.47dB/km
[3] Connector splicing loss: 0.5dB/pcs
[4] Dispersion = 3.5ps/nm*km
[5] Demux insertion loss = 2.5dB

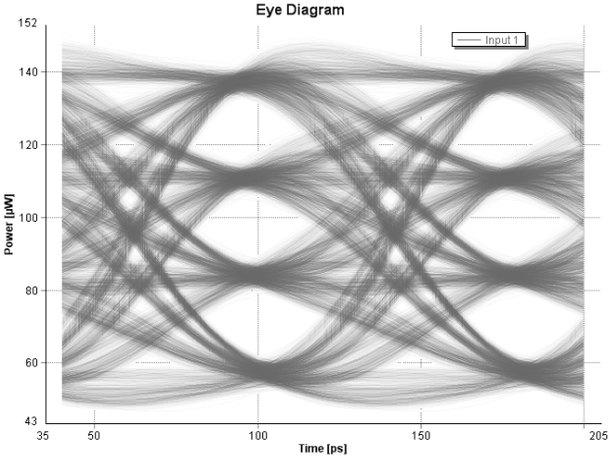
Rx

[6] Responsivity = 0.9A/W
[7] Band width of the receiver = 10GHz
[8] Dark current = 10nA
[9] TIA noise = 10pA/√Hz



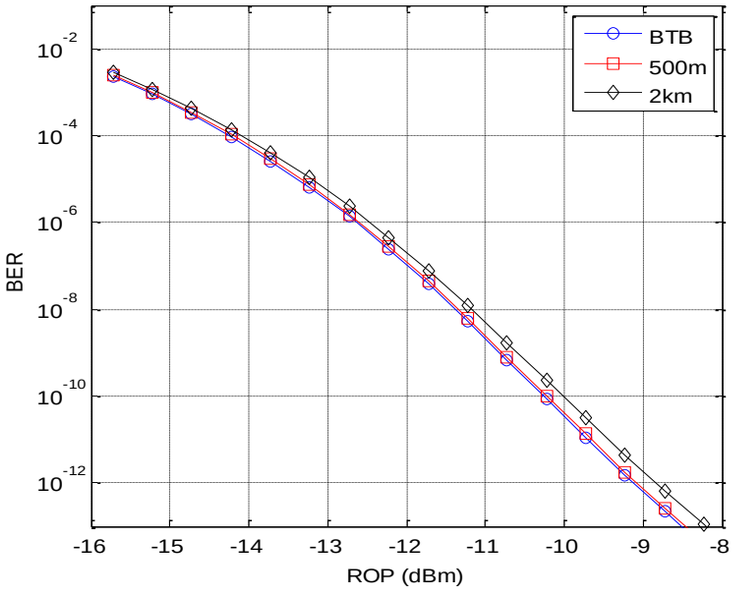


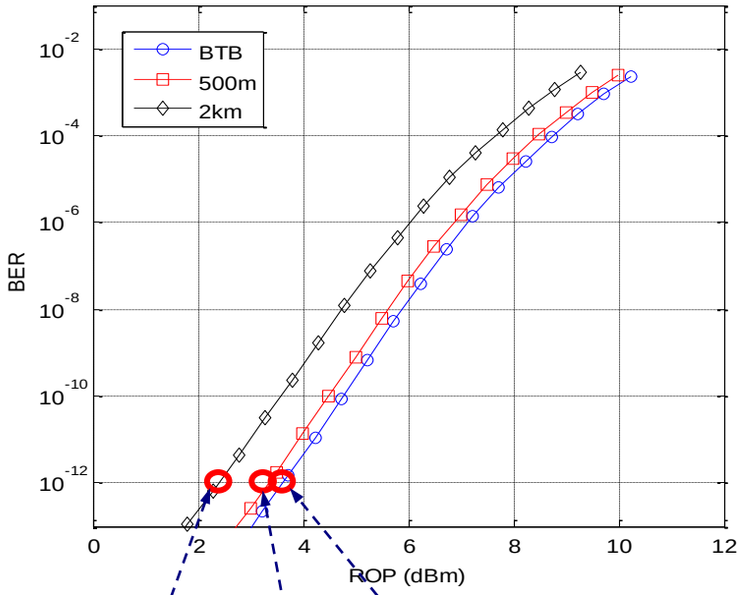
Eye after laser driver



Receiver performance after 2km SMF

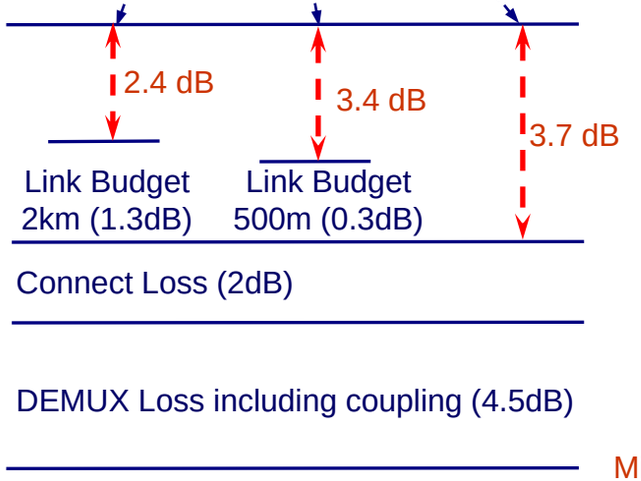
Simulation Verifications





System margin is reserved for impairments from optics, electronic components and transmission link;

And thus, technical feasibility of proposed 4x25Gb/s PAM-4 implementation is demonstrated for > 500m SMF.



Launch Pav per lane (1 dBm)

Margin

Link Budget

Min Receive Pav per lane (-9.2 dBm)

Scaling factors

- Similar relative cost analysis for NG100G PMDs is provided, as refer to nicholl_01_0112.

Item	DML (DFB)	EML (DFB + EAM, integrated)	DFB + MZM
Level of relative cost	Low	Medium	High

Item	CFP LR4		CFP2 LR4		4x25Gbps PAM-4	
	Description	Cost	Description	Cost	Description	Cost
TOSA	4x25Gbps discrete EML	1.00	4x25Gbps DML, integrated w/ Mux in TOSA	0.32	4x12.5GBaud DML integrated w/ Mux in TOSA	0.18
ROSA	4x25Gbps integrated ROSA	1.00	4x25Gbps PIN PD ROSA	1.00	4x12.5Gbaud PIN PD ROSA	0.69
O-Mux	Discreted O-Mux	1.00	Integrated in TOSA	N/A	Integrated in TOSA	N/A
O-Demux	Integrated in ROSA	N/A	Integrated in ROSA	N/A	Integrated in ROSA	N/A
Serdes	10x10→4x25 Gbps Gearbox	1.00	4x25 Gbps CDR	0.40	PAM-4 Serdes	0.30
Laser Driver IC	4x25Gbps EML Driver	1.00	4x25Gbps DML Driver	0.30	12.5GBaud DML Driver	0.20
Others	PCBA, housing, connector, IC, etc	1.00	PCBA, housing, connector, IC, etc	0.70	PCBA, housing, connector, IC, etc	0.60

Cost Trend Expectation

- Proposed PAM-4 approach is feasible for small form factor, i.e. CFP2 or CFP4, and follow a similar cost trend to 10GE optics for the time being.
- 10~12.5Gbps components are widely used in 10G and 40G applications, while the cost scales with volume and now has signification drop:
  - e.g. 10G transceiver, XFP/SFP+
  - e.g. 40G transceiver, CFP/QSFP+

Summary

- The PAM-4 solution proposed here offers considerable cost/power saving for high density SM applications, by taking advantage of mature 10G optics and components, and further reduction is expected through economics of scale and manufacture maturity.
- Technical feasibility is demonstrated from both IEEE publications and simulations verifications, while further experimental update will soon be available in next few meetings.
- Recommend the TF consider this PAM-4 approach that allows low cost, low power implementation for Next Gen 100GE PMD.

Thank you

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