Investigation of a 4x112Gbps PAM4 Configuration for the 2km SMF PMD

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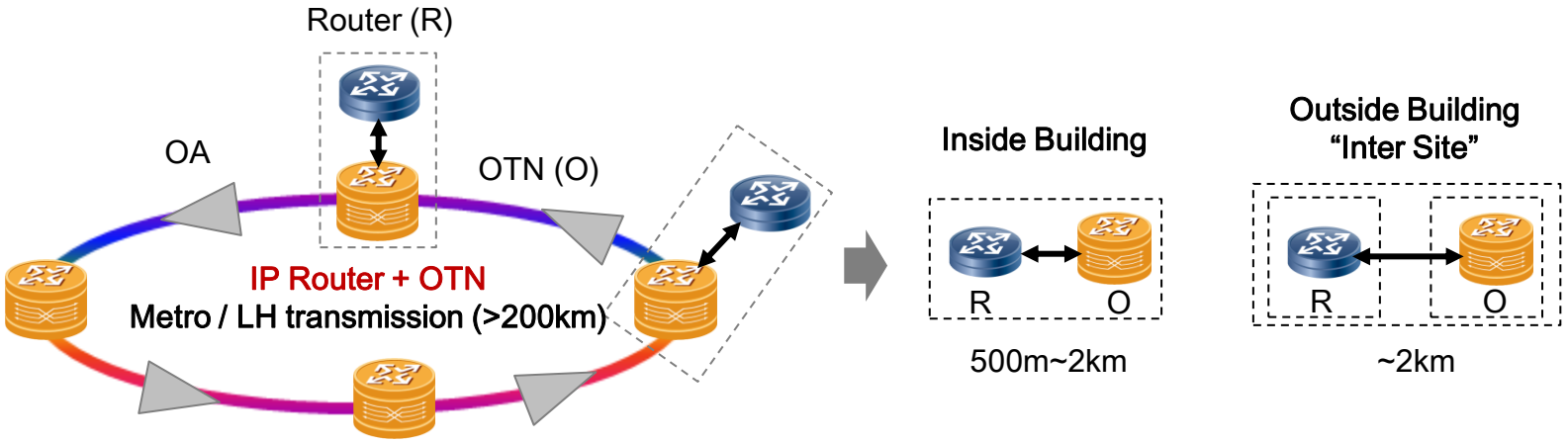
Outline

- Background Information
- Configuration of 4x112Gbps PAM4
- Experimental Demonstration of 4x112Gbps PAM4
- Options to Further Optimize the Module Architecture
- Summary

Background Information

- In the 400GE SG, “at least 2km over SMF” was adopted as one of the objectives.
- ~70% of router-OTN connections will be served by a 2km fiber PMD solution [1] and 2km is also needed for datacenters.



- According to the motion results as the table below, undoubtedly, this 2km duplex SMF application enables a “broader market” for Ethernet. [2]

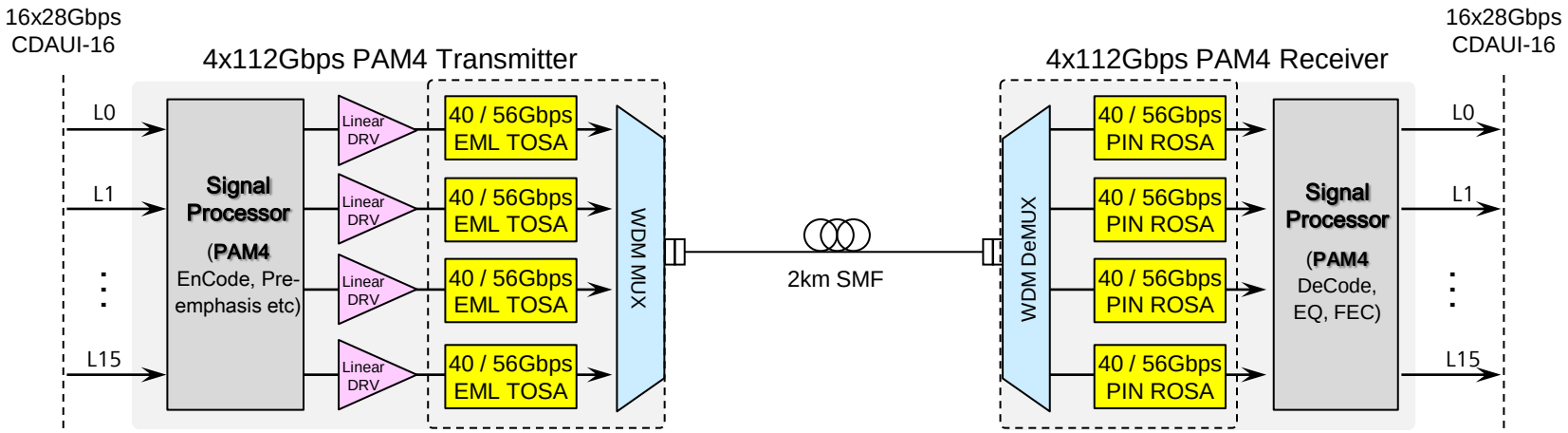
Item	At least 100m over MMF	At least 500m over SMF	At least 2km over SMF	At least 10km over SMF
Y	84	80	99	82
N	8	7	5	20
A	26	29	8	23
Approval Ratings	91%	92%	95%	80%

[1] song_x_400_01a_1113, dove_400_01_0114.
[2] minutes_400_01b_1113_unapproved.

Introduction

- Several single-lambda 100Gbps configurations have been mentioned for 400GE.
- This presentation will provide information on a 4x112Gbps PAM4 (400GBASE-FR4) approach and investigation results to support the technical feasibility of the 2km objective based upon current commercial components.
- There are lots of topics for future study which we will continue to work on.

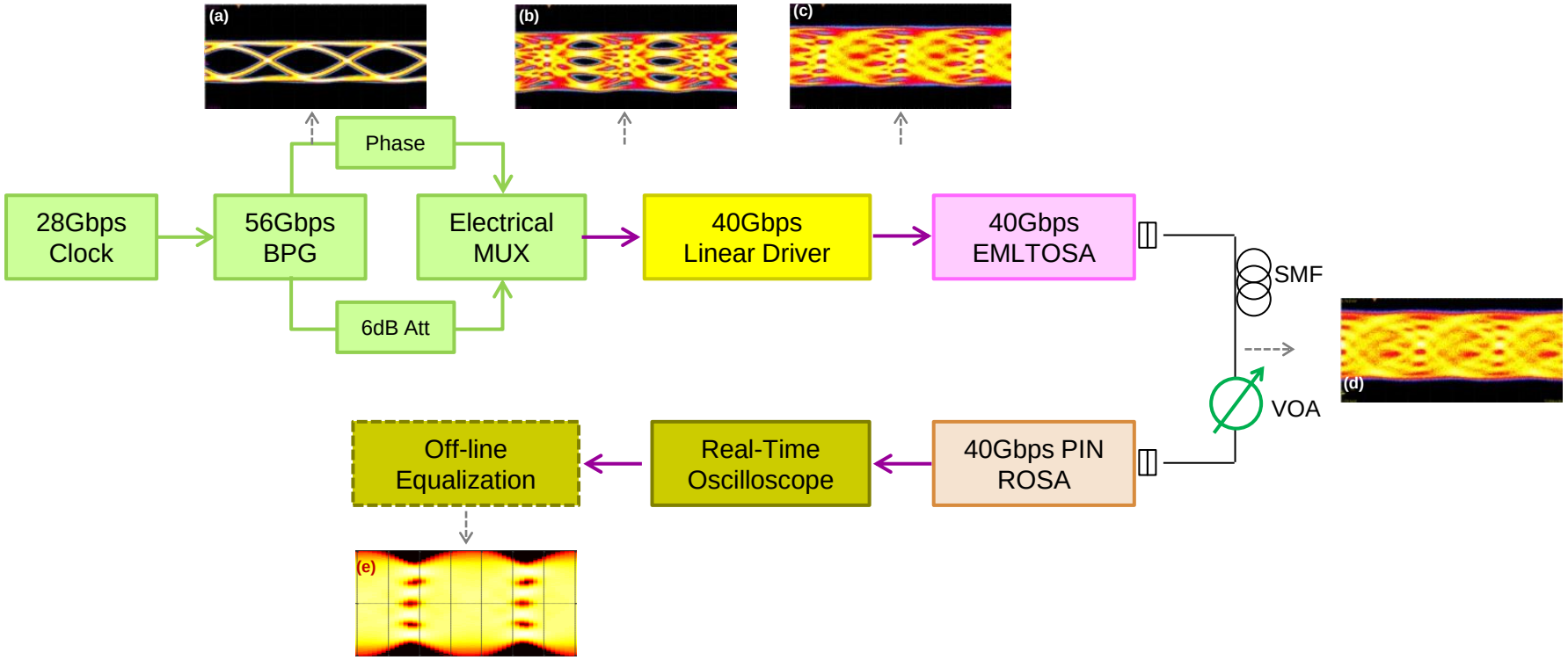
Configuration of 4x112Gbps PAM4



- A 4x112Gbps PAM4 configuration with the 100G-LR4 LAN-WDM wavelengths is a potential solution for the 400GE 2km PMD .
- We assume a CDAUI-16 electrical interface.
- High-bandwidth optical devices will be needed to enable 112Gbps PAM4 modulation, such as EML TOSA and PIN ROSA with BW around 40G-class.
- PAM4 coding/decoding, equalization and FEC is foreseen.

Experimental Demonstration of 4x112Gbps PAM4 for 2km

Experimental setup of 4x112Gbps PAM4



Transmitter:

TOSA: 40Gbps EML, 32GHz BW, 6dB ER

Driver: 40Gbps linear driver, ~32GHz BW

Receiver:

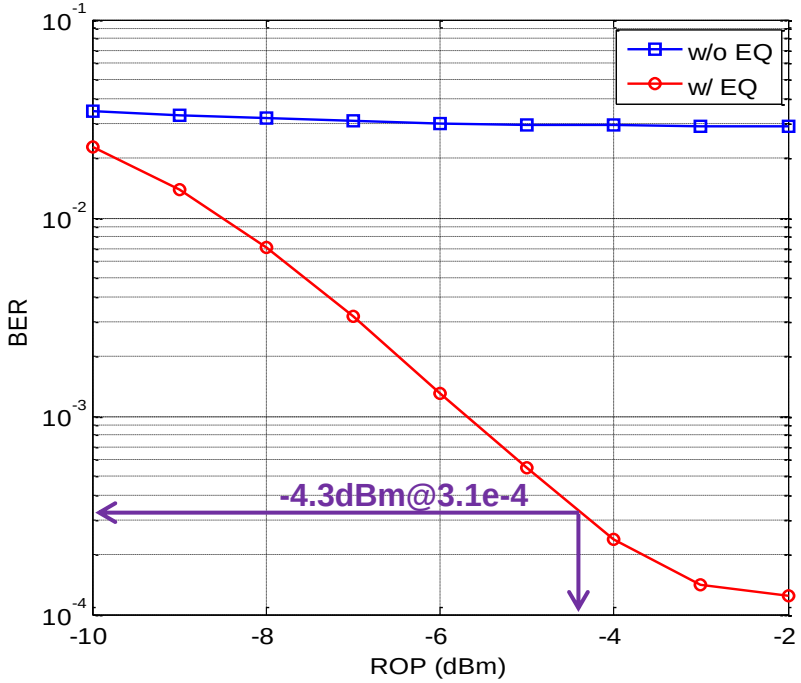
ROSA: 40Gbps PIN-PD, linear TIA

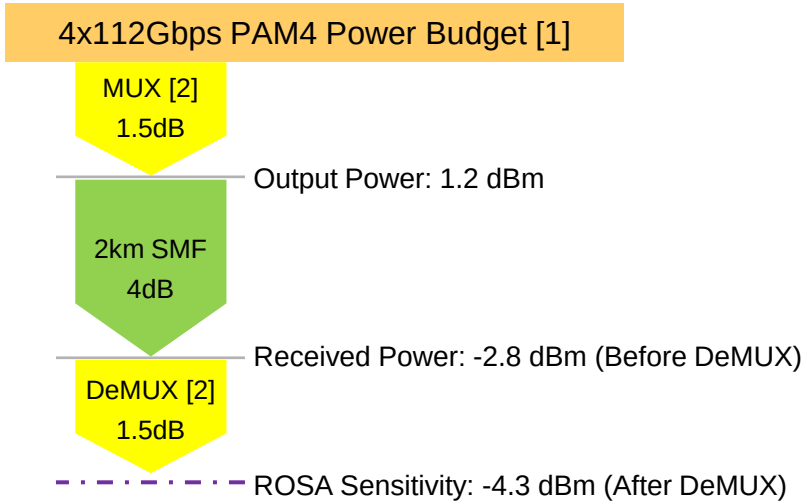
Real-time scope: BW 33GHz, sampling rate 80GS/s

Number of FFE taps: 13-taps

Experimental Demonstration of 4x112Gbps PAM4 for 2km

BER test results and optical power allocation





[1] It is a rough power budget for our first step test.
[2] It is a 4 lanes MUX / DeMUX, which we assume to be consistent with existing 100G-LR4 passive parts.

- Preliminary 112Gbps PAM4 experiments have been carried out, which were based upon commercial 40Gbps devices.
- The ROP of -4.3dBm@3.1e-4 has been achieved with equalization.

Options to Further Optimize the Module Architecture

- In order to reduce the bandwidth requirements for the optical devices, algorithms such as FTN (Faster-Than-Nyquist) will be investigated.
- FTN concept is proposed in 1975 by Mazo [1], and the technology has attracted interest today because it can pack 25% more data in the same bandwidth at the same energy per bit and error rate compared to traditional methods.
- In this study we will also investigate the implications of these algorithms, e.g. increase of power consumption, impact on latency, etcetera.

[1] J. E. Mazo, “Faster-than-Nyquist signaling,” Bell System Tech. J. 54(8) 1451-1462 (1975).

Summary

- 4x112Gbps PAM4 is under consideration as a candidate for the 400GE 2km SMF objective.
- According to current test results, using commercial components, 4x112Gbps PAM4 was demonstrated to be a promising candidate for 2km SMF.
- We are continuing to study this and there are several key parameters that should be improved:
  - Bandwidth of cables and connectors
  - Optimize the linearity of O/E components and reduce the noise of drivers
  - Investigate the minimum bandwidth needed for the various key components
  - Investigate the worst case chromatic dispersion penalty
- The introduction of FTN perhaps may be a promising method to reduce the bandwidth requirements for optical components (and its related cost) in a 4x112Gbps PAM4, using low-cost optical devices (25Gbps instead of 40Gbps devices). We intend to investigate this in a PAM4 system.
- We intend to continue this investigation and, depending on the further results, intend to prepare a proposal for a 4x112Gbps PAM4 based PMD for 2km SMF.

Thank you