

Roadmap of 400GbE SMF PMDs for Telecom Applications

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Supporter

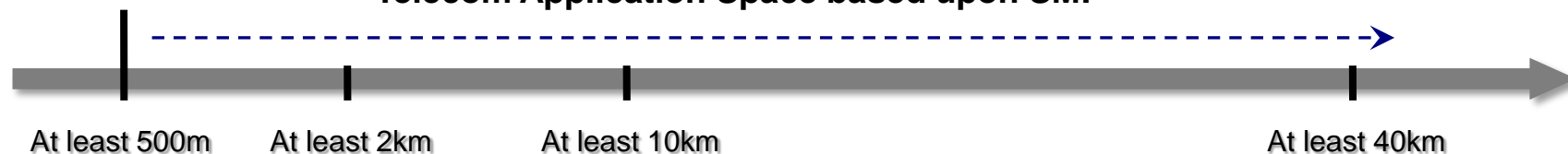
- Haiyi Zhang, CATR
- Wenyu Zhao, CATR
- Ryan Yu, Oplink
- Keith Conroy, Multiphy
- Wenbin Jiang, Cosemi
- Hongchun Xu, Accelink
- Qianggao Hu, Accelink

Outline

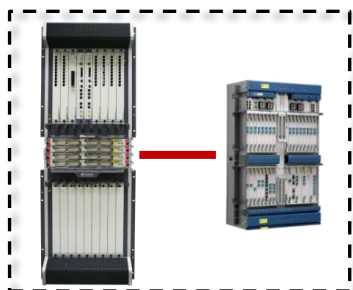
- ❑ Motivation and Application Space of 400GbE SMF
- ❑ Evolution of SerDes Technology
- ❑ Possible Roadmap of 400GbE SMF PMDs
- ❑ Potential Candidates of 400GbE SMF PMDs
- ❑ Summary

Motivation and Application Space of 400GbE SMF

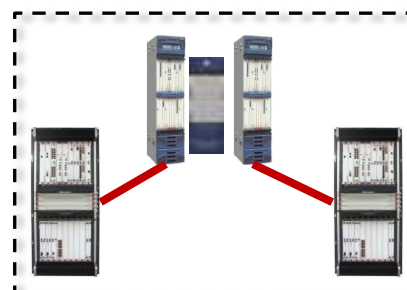
Telecom Application Space based upon SMF



Connections between IP Core Routers and OTN



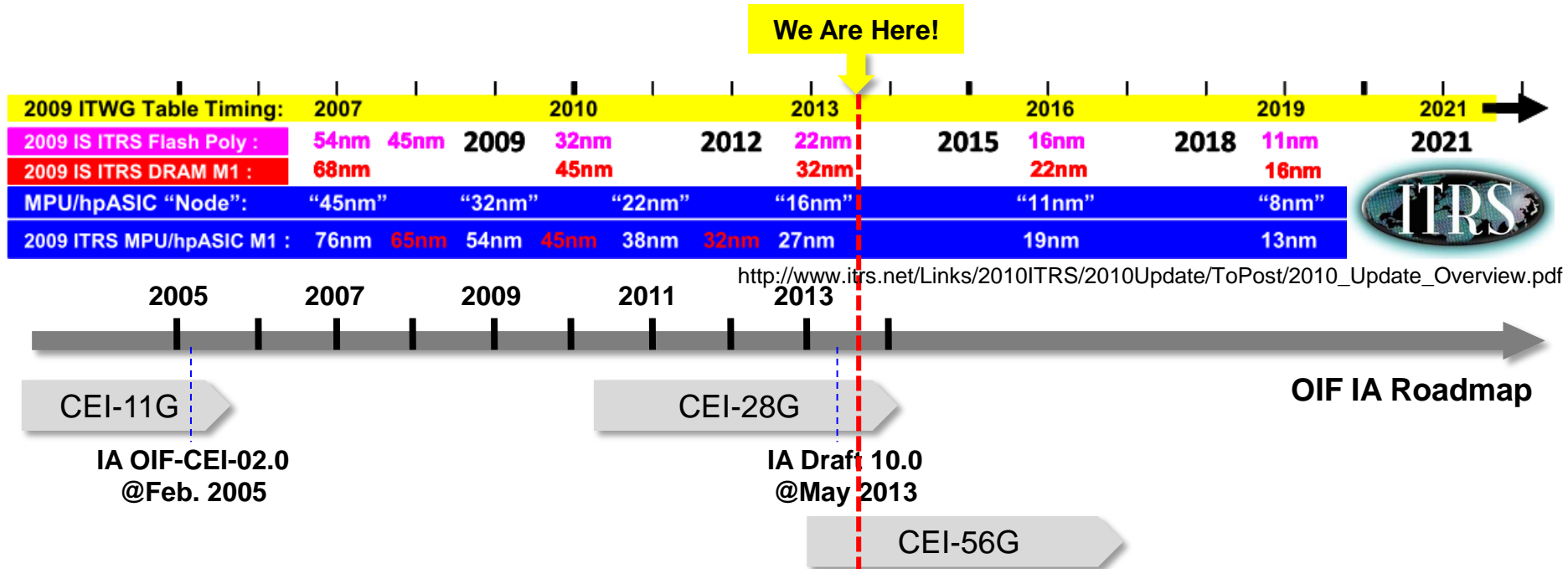
Connections between IP Routers



- Telecom application is an important domain for the first adoption of 400GbE.
 - ✓ Connections between IP Routers suggest an SMF distance objective of 10km, and additionally 40km for some of the Metro applications. Duplex fiber solutions are regarded necessary for both applications.
 - ✓ Connections between IP Core Routers and OTN equipments, suggest SMF distance objective of 2km. Also in this case Duplex fiber solutions are regarded necessary.
- So we definitely need an SMF distance objective of 10km.
- If we can generate a specification for at least 2km which enables a significantly lower cost solution than for 10km then a 2km SMF objective should be added.

Evolution of SerDes Technology

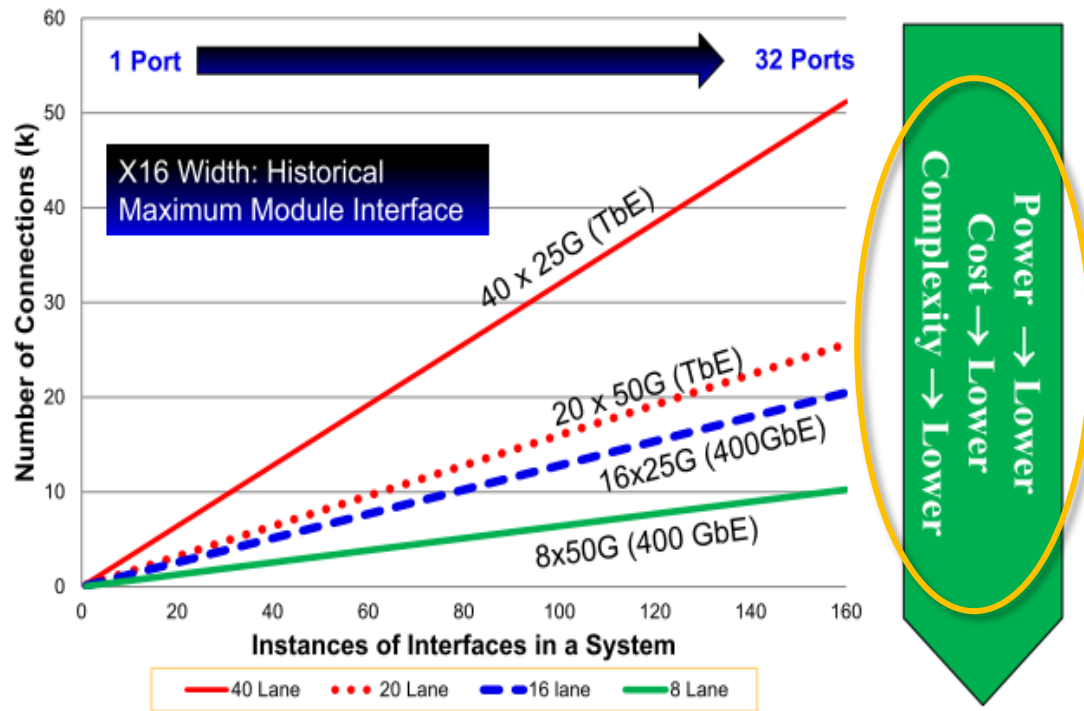
Roadmap of CMOS Process from ITRS



- Overview of CMOS international technology roadmap for semiconductors at 2010.
- 28Gbps SerDes core has been demonstrated by several companies to be compliant with the Common Electrical Interface (CEI) standard in recent years. 28Gbps and its related platform should be sufficiently mature by the time the first version of a 400GbE standard will be ready.
- The discussion of CEI-56G started in the OIF in 2013. There are some doubts whether this technology will be sufficiently mature in time for the first generation of 400GE specification, ongoing industry debate is about the modulation format (NRZ, PAM4 or other advanced modulation format) in electrical interfaces.

Options for 400GbE SMF PMDs

- In the same way as for 40GbE and 100GbE, multi-lane solutions are unavoidable for 400GbE, e.g. 16x25Gbps, 8x50Gbps and 4x100Gbps.

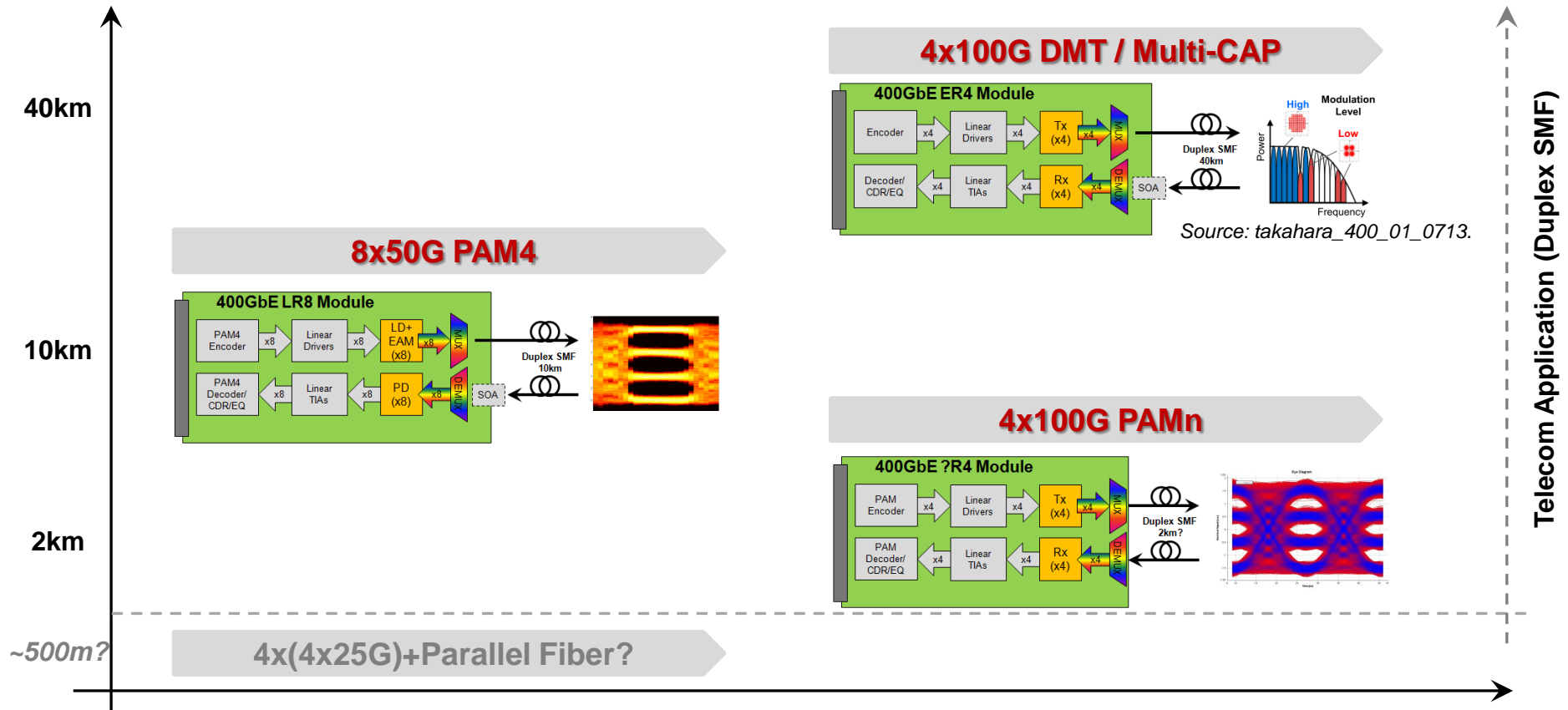


Source: CFI_01_0313.

- For both electrical and optical interfaces, in order to limit the number of specification generations and to achieve the highest, economically feasible device density, we should try to reduce the number of lanes as much as possible, at least from 16 to 8 or even 4, especially the optical lanes.

- After we agree on the number of optical lanes, the technologies used should be sufficiently mature, manufacturable and testable. Specification methodology enabling interworking should be available as well.

Possible Roadmap of 400GbE SMF PMDs



Phase 1: Leverage mature technologies

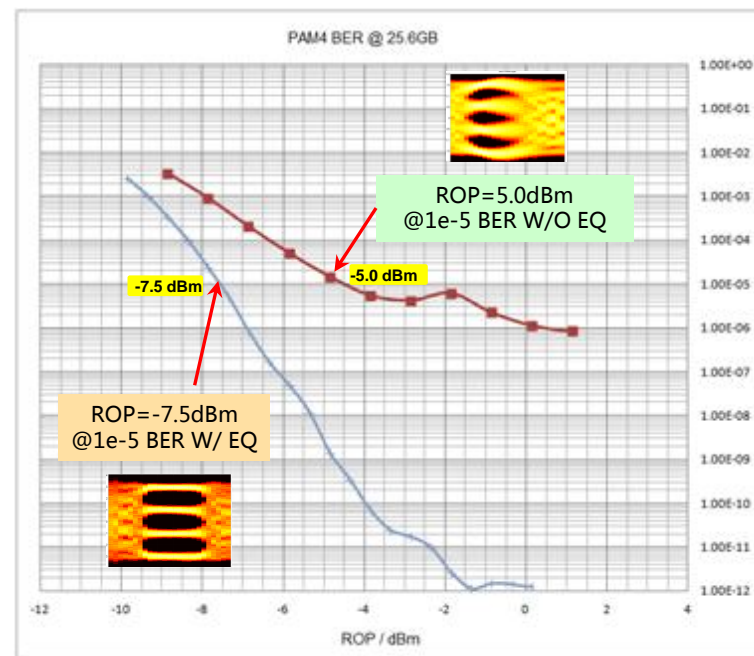
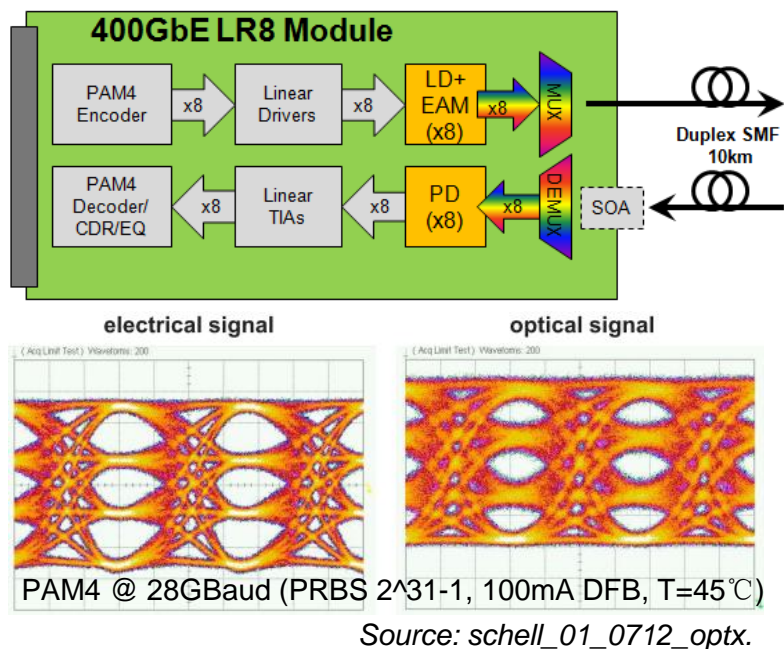
- ✓ Based on the 25/28Gbps platform, a limited advanced modulation format and FEC (e.g. RS-FEC).
- ✓ The O/E components can remain at 25Gbps-class, or reusing similar components of 100GbE, and leverage the high volume 100GbE market.

Phase 2: Introducing new technologies

- ✓ Introducing more advanced modulation formats or higher bandwidth components.
- ✓ Using stronger FEC, new electrical interface and the test methods (equipments), which we will know more in the future.

Potential Candidates of Gen 1 for 400GbE SMF PMDs

8x50Gbps PAM4 Optics

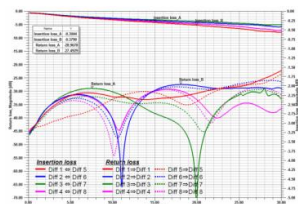


- Based upon today's experience and past discussions in 802.3bm, we find that an approach based upon 8 optical lanes, each operating at 50Gbps PAM4 could be a very promising solution.
- 8x50Gbps PAM4 for 10km (w/ FEC & EQ & SOA).
- Further experimental results will be shown in future meetings.
- Suggestions for further experiments are invited.

Potential Candidates of Gen 1 for 400GbE SMF PMDs (Cont'd)

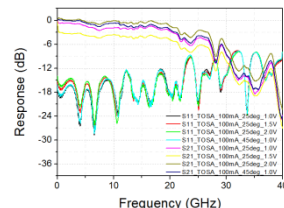
8x50Gbps PAM4 Optics

25G Housing RF Interface



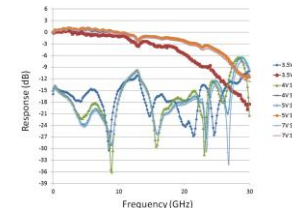
Source: wli_01_0713_optx

S21&S11 of 25G EML TOSA



Source: test results based on commercial products

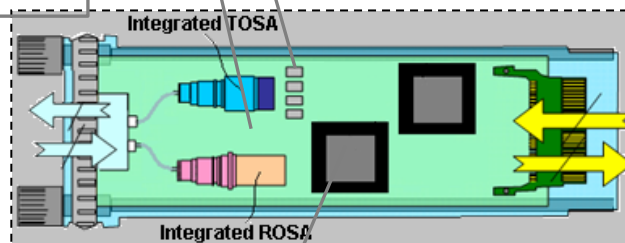
S21&S11 of 25G EML Driver



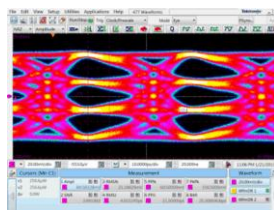
Source: test results based on commercial products

- ✓ 8 Lanes integrated TOSA and ROSA.
- ✓ The optical components can remain at 25GBaud, reusing similar components of 100GbE, and leverage the high volume 100GbE market.

- ✓ 8 Lanes linear Drivers.
- ✓ The electrical can remain at 25GBaud, reusing similar components of 100GbE with the consideration of linearity performance.



Electrical eye of 50Gbps PAM4

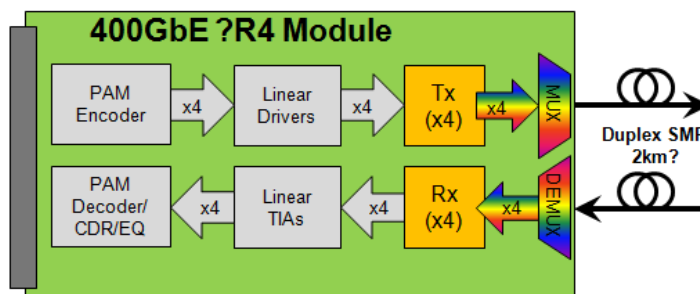


- ✓ Leverage the PAM4 technologies studied in 802.3bj and the evolution towards to the high speed.
- ✓ To achieve lowest cost and not too tight specifications for 400GbE, it is unavoidable to use FEC and Equalizer.

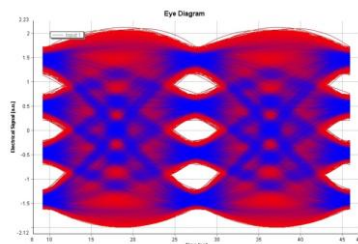
- To address the emerging needs for 400GbE applications and to enable quick time to the market a solution based upon scaling up mature 25/28Gbps technologies to e.g. 8x50Gbps PAM4 would be preferred.

Potential Candidates of Gen 2 for 400GbE SMF PMDs

4x100Gbps PAMn Optics

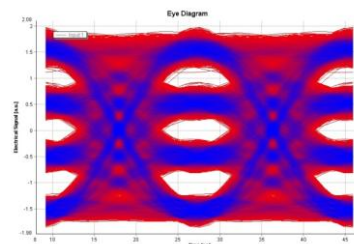


4x100Gbps PAM4 Simulation
Based upon **25Gbps** Components



Simulation eye (w/ EQ)

4x100Gbps PAM4 Simulation
Based upon **40Gbps** Components

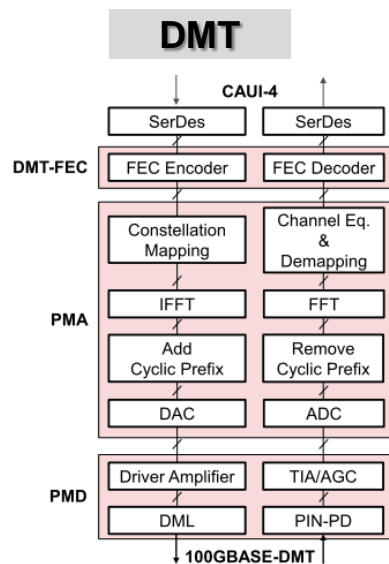


Simulation eye (w/ EQ)

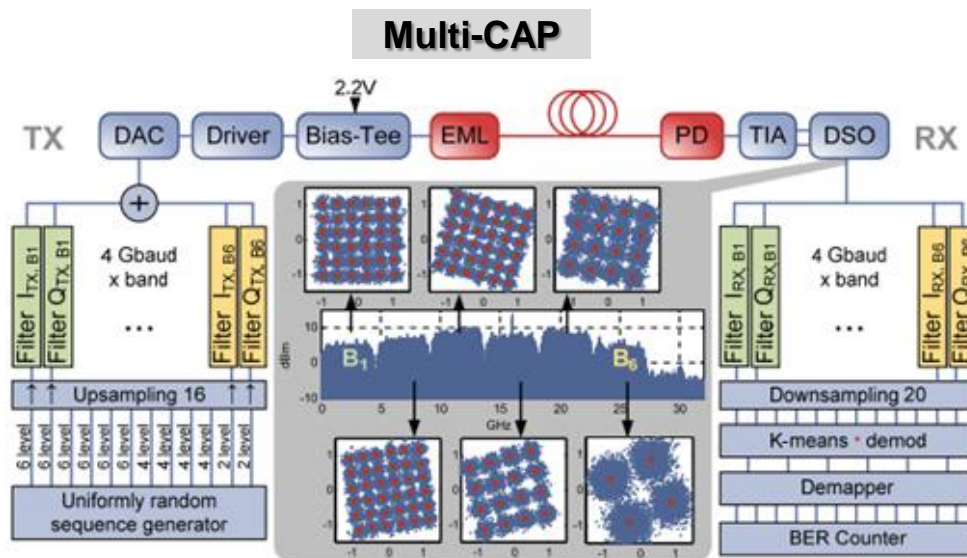
- Potential future architectures using advanced modulation (e.g. PAMn etc) may reduce address limitations of size, power consumption and cost for high density applications.
- 4x100Gbps PAM4 may be a potential candidate for 2km based upon simulation results (w/ FEC & EQ), but the industry need to start the research on the higher bandwidth E/O components, low noise receiver, equalizer and stronger FEC etc to further investigate the technical feasibility.
- Candidate electrical I/O lane rates will be 50Gbps, and the chip-to-module electrical I/O is now being discussed in the OIF CEI-56G-VSR project.

Potential Candidates of Gen 2 for 400GbE SMF PMDs (Cont'd)

4x100Gbps DMT / Multi-CAP



Source: *tanaka_01_0513_optx*.



Source: *PDP5C.10 OFC 2013*.

- Considering the characteristic like overcoming the link chromatic dispersion by introducing the sub-carrier, DMT and Multi-CAP would be the potential candidates for 40km SMF scenario.
- For FEC, a “802.3bj like” FEC may not be sufficient to meet the requirements of 4x100Gbps candidates, so we need more time to study possible advantages of a stronger FEC.
- Further investigations are needed, e.g. the technical feasibility of DMT and Multi-CAP, the algorithm, and the definition method of Tx/Rx performance etc, to ensure multi-vendor interoperability.

Summary

- Proposed Objectives of SMF PMDs for the 400GbE Study Group:
 - At least 2km over duplex SMF
 - At least 10km over duplex SMF
 - At least 40km over duplex SMF (1st or 2nd generation?)
- To enable the quick time to the market, a 8x50Gbps PAM4 architecture, scaling up mature 25/28Gbps platforms and leveraging the technology of 100GbE generations, may be a promising candidate to satisfy a 10km SMF objective, 400GbE telecom applications and the fast growth Ethernet bandwidth.
- A four lane solution based upon a 4x100Gbps PAMn architecture, with potential economic advantages in the future, may be a candidate solution for 2km applications and not for 10km because of expected performance limitations.
- DMT and Multi-CAP may be potential candidates to satisfy 40km SMF objectives, but research is needed on the modulation format and the algorithm to ensure the interconnection and interworking. We may need to discuss to put a 40km objective in the second generation of the 400GbE specification.

Next Investigation Step

- The use of Advanced Modulation formats for 400GbE is unavoidable to establish the required balance between cost, power and density for the different scenarios.
- We propose to start investigate the performance of advanced modulation for 400GbE SMF PMDs:
 - To perform a technical feasibility study using simulations AND experiments to verify the performance of the various modulation formats.
 - To enable the choice of an appropriate modulation format for the different scenarios.
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Thank you