Advanced Modulation for Next Gen 100GbE SMF PMD

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Overview

- Recap on Objectives
- Recap on Study Group discussions
- Advanced Modulation
  - Background and Drivers
  - What is it ?
  - Sample proposals
  - Progress update since July and Next Steps
- Summary

802.3bm 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

Source: http://www.ieee802.org/3/bm/Objectives.pdf

Further clarification on 100G SMF Objective

The following clarification related to the 100G SMF objective, was included as part of the 5 Criteria Presentation[1]

"The amendment will enable new PHY types over SMF which consist of the existing 100GBASELR4 and 100GBASE-ER4 optical PMDs with four electrical interconnect lanes in each direction. The amendment will define a new 100 Gb/s SMF PMD in addition to these if it can be shown that a SMF PMD with a shorter reach than 100GBASE-LR4 has sufficient cost, density, or power difference to justify an additional SMF PMD type."

1. http://www.ieee802.org/3/bm/5Criteria.pdf

It's all about Cost !

- The primary driver for a new 100G SMF PMD is cost
- nowell_01_1111:

  A "step function reduction" in system cost is needed to justify a new SMF PMD"

- A straw ballot held in Atlanta provided some insight into the Study Group's definition of 'step function reduction':

Strawpoll 3 (Chicago rules)
A: I would be interested in a PMD supporting a 500m reach at 75% the cost of 100GBASE-LR4
B: I would be interested in a PMD supporting a 500m reach at 50% the cost of 100GBASE-LR4
C: I would be interested in a PMD supporting a 500m reach at 25% the cost of 100GBASE-LR4
A:1 B:10 C:40

The Bottom Line ….

Related to a new 100G SMF PMD we have been tasked to:

- Define one, and only one, new 100G SMF PMD
- ONLY define a new PMD type if it provides a sufficient improvement in Cost, Density and Power over the existing 100GBASE-LR4 PMD

An acceptable outcome is “Do Nothing” !

Solutions discussed in Study Group

1) Do Nothing

100GBASE-LR4 remains as the sole option. Let volume/time/technology maturity drive cost reduction. The default solution.

2) 4x25G CWDM

Minor modification to LR4. Wider wavelength spacing eliminates need for cooler. Not viewed as adding significant cost reduction. Splits the LR4 market ?

3) PSM4

Adoption of SMF ribbon technology. 4x25G. ~500m. Highly leveraging MMF transceiver (array) technology to achieve cost reductions. Some concern over adoption of new cable type in data center.

4) Advanced Modulation

Based upon assumption that optics is the dominate cost drive. Proposal is to leverage advanced modulation to move complexity into electronics and reduce optics down to (ideally) a single laser and receiver . Early work was mainly on PAM-N based solutions, but alternative modulation and coding schemes are now being investigated.

Snapshot of 100G SMF PMD Contributions

Meeting	General Contribution	CWDM	PSM4	Advanced Mod
Chicago Sept/11	4			
Atlanta Nov/11	5		1	
Newport Beach Jan/12	2	1	3	4
Big Island, Hawaii Mar/12	4	1	4	10
Minneapolis, MN May/12			2	8
San Diego July/12	1	2		6
TOTAL	16	4	10	28

Advanced Mod – Background and Drivers

Underlying assumption is that optical component count, associated packaging, and number of fibers are the dominant cost driver.

"Reduction of number of components is key to achieve the lowest cost solution for data center application" (Source: anderson_01_1111[1])

The goal of advanced modulation is to move complexity into the electronics in a attempt to simplify the optics.

100G Serial (i.e. single wavelength) ?

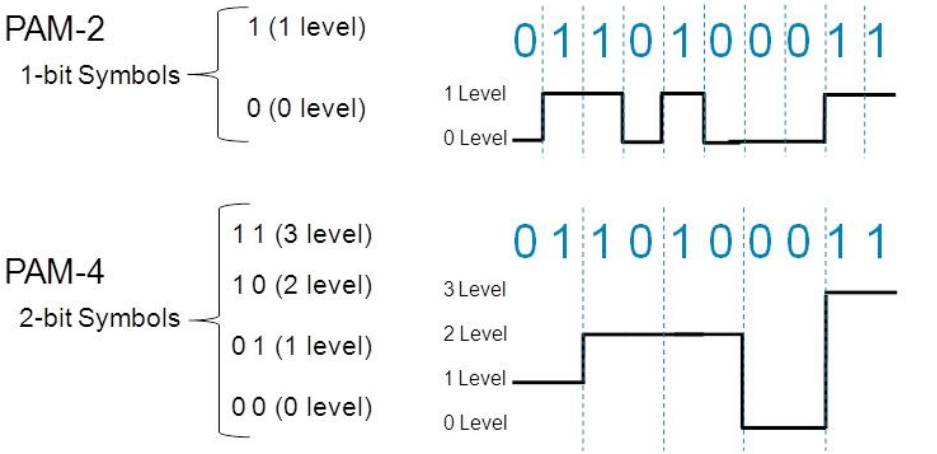
1: http://www.ieee802.org/3/100GNGOPTX/public/nov11/anderson_01_1111_NG100GOPTX.pdf

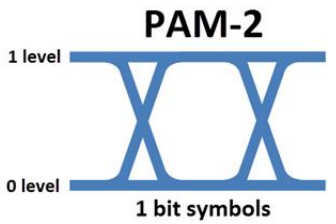
Advanced Mod – What is it (1) ?

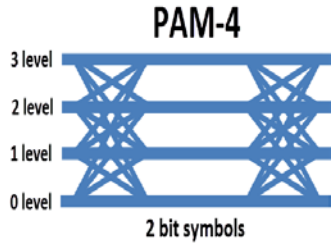
Four primary ways to increase the optical data rate:

1. Increase the transmission frequency, or
2. Increase the number of fibers, or
3. Increase the number of wavelengths per fiber, or
4. Increase the number of bits per symbol

Advanced modulation is primarily targeted at #4







Advanced Mod – What is it (2) ?

Advanced modulation for optics is not new. Widely used for Long Haul & Metro over the past few years:

- 40G: Duobinary, DQPSK, QPSK, BPSK
- 100G: QPSK and more …
- 400G: 16QAM, etc ..

Advanced modulation for “Client Optics” has different drivers than Long Haul & Metro:

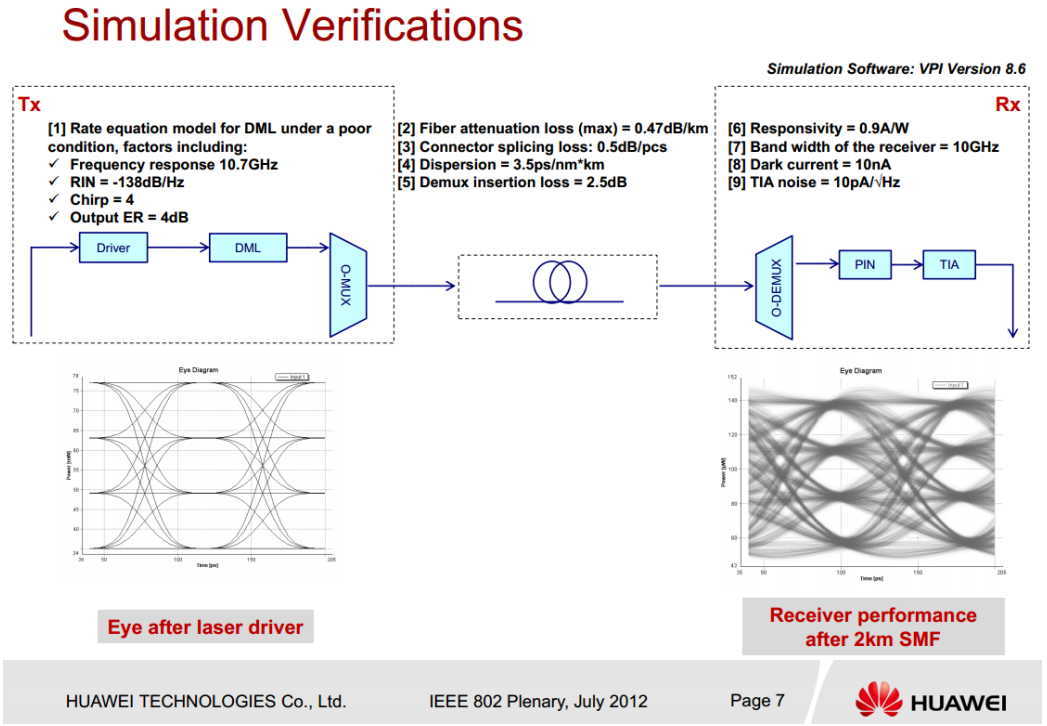
- Long Haul/Metro >> Optical Performance
- Client Optics >> Density and Cost
- Infers a different modulation solution for client optics ?

Sample Proposal @ July IEEE (1)

cui_01_0712_optx.pdf *

Proposal leverages WDM and Advanced Modulation to enable high bit rate transmission @ low cost

- 2 bits per Symbol
- 4 Wavelengths
- Use lower speed (cost) DMLs



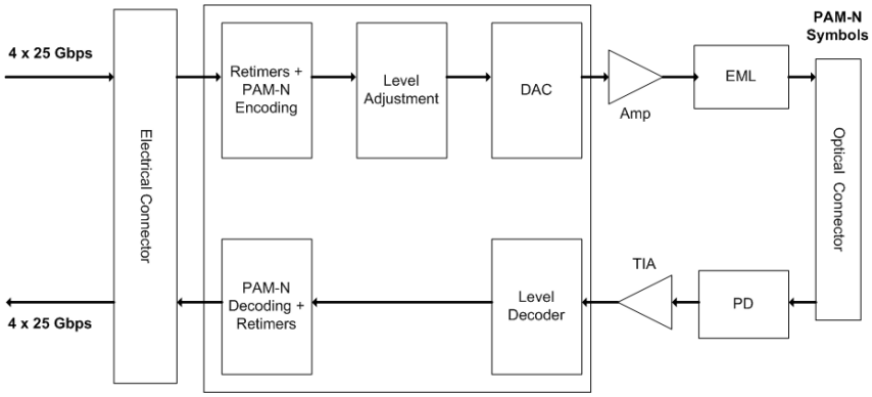
See *: http://www.ieee802.org/3/100GNGOPTX/public/jul12/cui_01_0712_optx.pdf

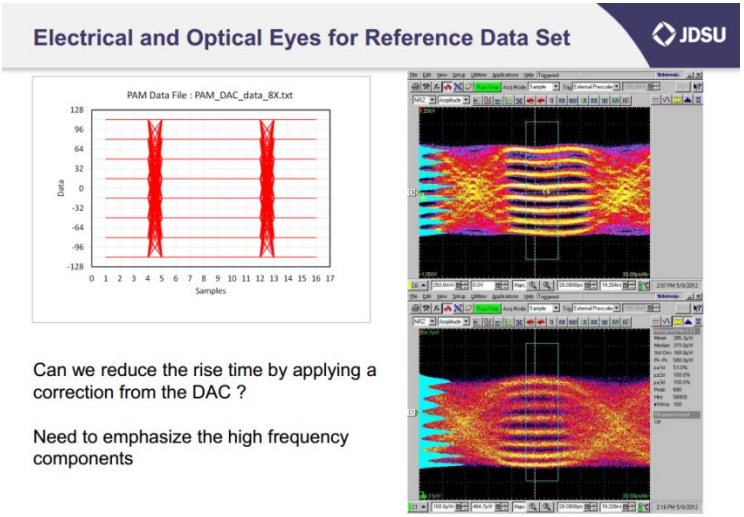
Sample Proposal @ July IEEE (2)

lewis_01a_0712_optx.pdf *

These results highlight a PAM-8 implementation

- 3 bits per Symbol
- DAC (Digital to Analog Convertor)
- Using EML as light source & modulator
- Spectral shaping investigated



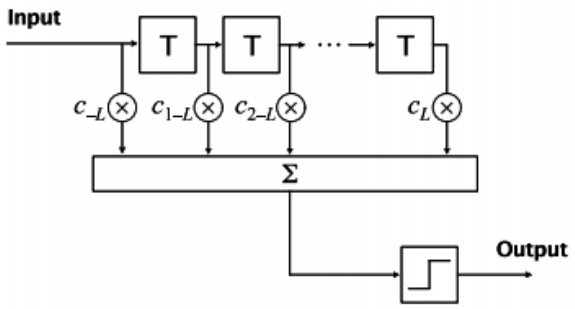


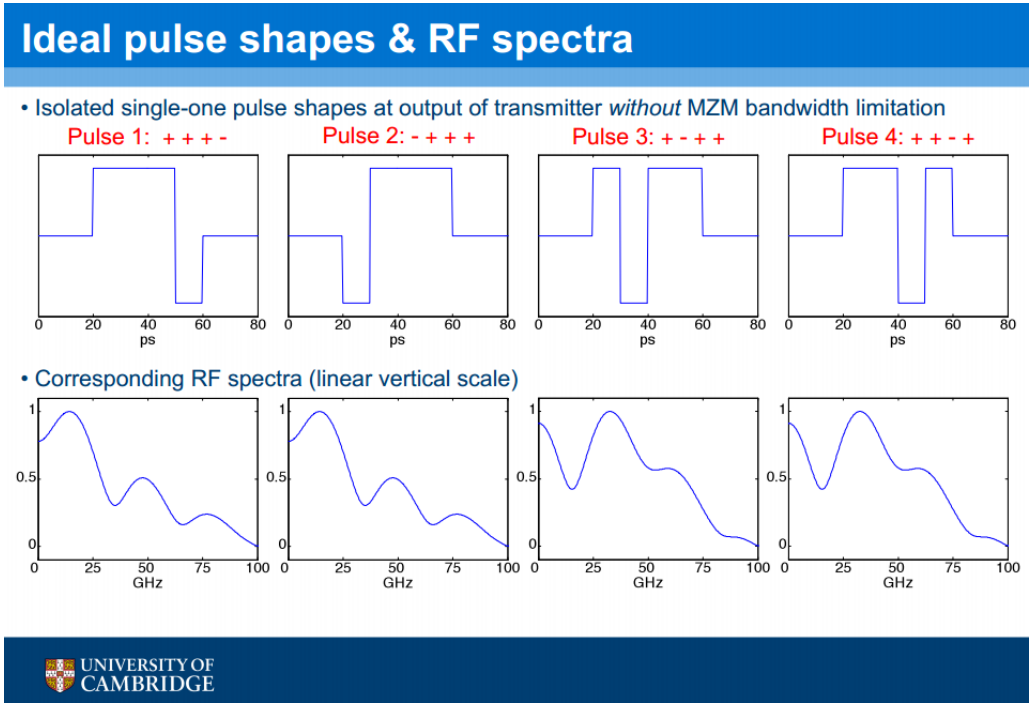
See *: http://www.ieee802.org/3/100GNGOPTX/public/jul12/lewis_01a_0712_optx.pdf

Sample Proposal @ July IEEE (3)

ingham_01a_0712_optx.pdf *

Multipulse Modulation is proposed leveraging transversal filters to create orthogonal signals





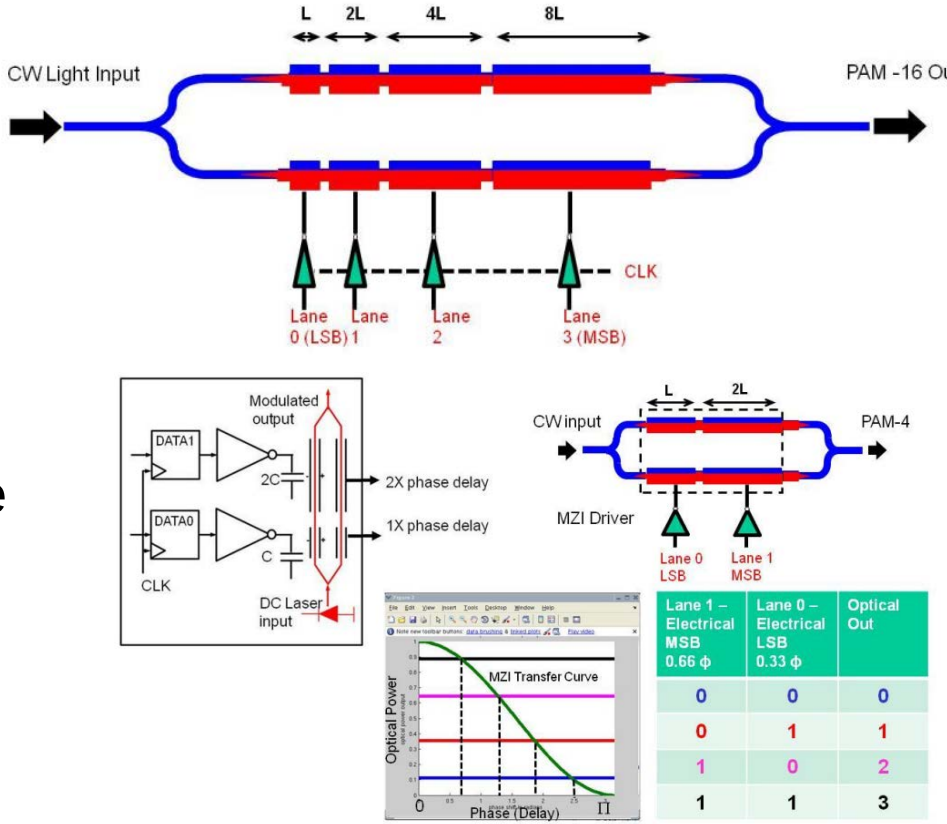
See *: http://www.ieee802.org/3/100GNGOPTX/public/jul12/ingham_01a_0712_optx.pdf

Sample Proposal @ July IEEE (4)

nicholl_01_0712_optx.pdf *

PAM-16 is proposed using a Silicon Photonics based segmented MZI

- 4 bits per Symbol (PAM 16)
- Segmented MZI implements simple Optical DAC
- DAC performance defined by lithography
- Low cost CW laser light source



Lane 1 – Electrical MSB 0.66 ϕ	Lane 0 – Electrical LSB 0.33 ϕ	Optical Out
0	0	0
0	1	1
1	0	2
1	1	3

Segmented MZI + Simple Digital Driver > DAC function for PAM

3

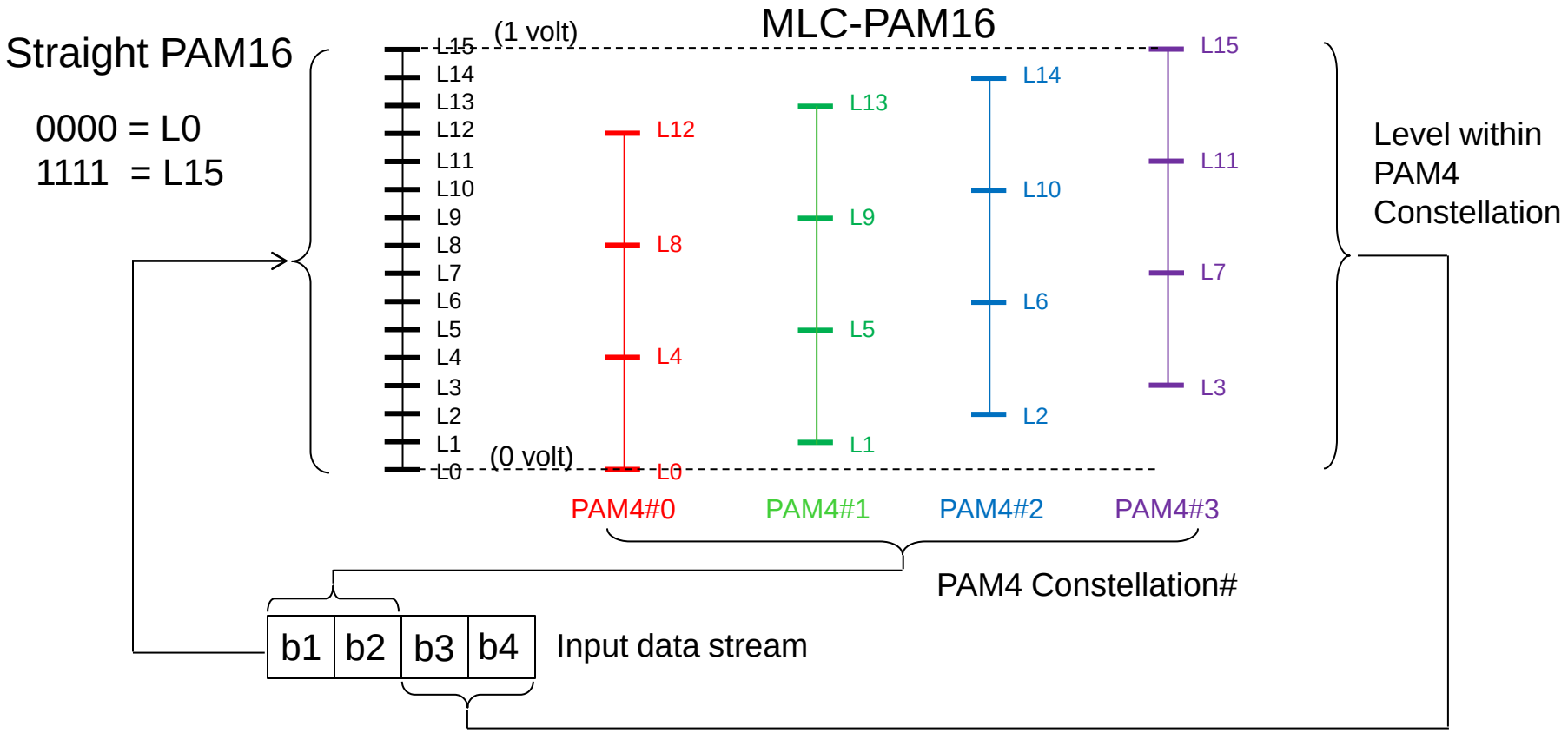
See *: http://www.ieee802.org/3/100GNGOPTX/public/jul12/nicholl_01_0712_optx.pdf

Progress since July

- Significant uptake in terms of broad industry engagement and level of technical analysis.
- Starting to reconcile the different analysis approaches (link budget parameters, simulation environment, component parameters, etc)
- A PAM-n based solution remains the focus of attention by many, considering the combination of technical and economic feasibility
- Exploring the use of advanced coding/mapping schemes to provide additional link margin to make multiple PAM schemes feasible.

Note: Animated in Slide Show

Multi Level Coding (MLC)



- MLC – Not all bits are equal. Focus FEC overhead/gain where it adds the most value
- Treat upper two bits (b1,b2) as “PAM16”. Treat lower two bits (b3,b4) as “PAM4”
- Target all FEC overhead/gain to protecting the upper two bits, and no FEC to lower two bits
- Enables higher FEC coding gain without bumping up the symbol (data) rate
- e.g. a 20% overhead FEC on upper two bits, only results on 10% overhead on aggregate

Next Steps

- Further reconcile the analysis between the different groups and individuals
- Start building consensus towards a single advanced modulation (likely PAM-N based) proposal
- A better understanding of the trade-offs between the different solutions in terms of implementation complexity, power, latency, cost, etc will be critical in driving consensus towards a single solution going forward.

Summary

- 802.3bm objective is to develop a new 100G SMF PMD that provides a ‘step function reduction’ in cost over 100GBASE-LR4
- Advanced Modulation provides a path to that step reduction in cost, via reduced optical component count and associated packaging
- Significant progress in terms of broad industry engagement and level of technical analysis. Several robust and feasible proposals presented.
- PAM-N , potentially with advanced coding, is the leading candidate and solid technical feasibility has been presented.

Final word …..

Advanced Modulation is “Advancing“