

Using EDC to Relax Component Specifications

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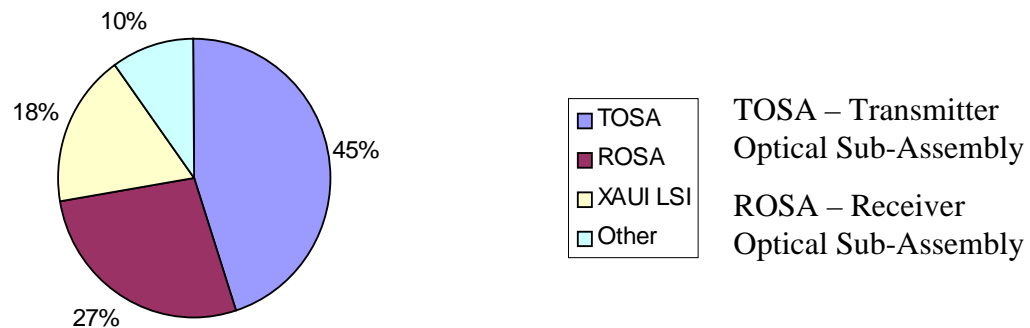
Motivation

- 10-Gbit/s EDC standard should solve two key problems:
 - Achieve 300m over FDDI MMF
 - Reduce cost of the 10-Gbit/s optical modules used for 300m applications
- Support both Technical and Economic Feasibility efforts of Study Group
- Details to follow in Task Force

Module Cost

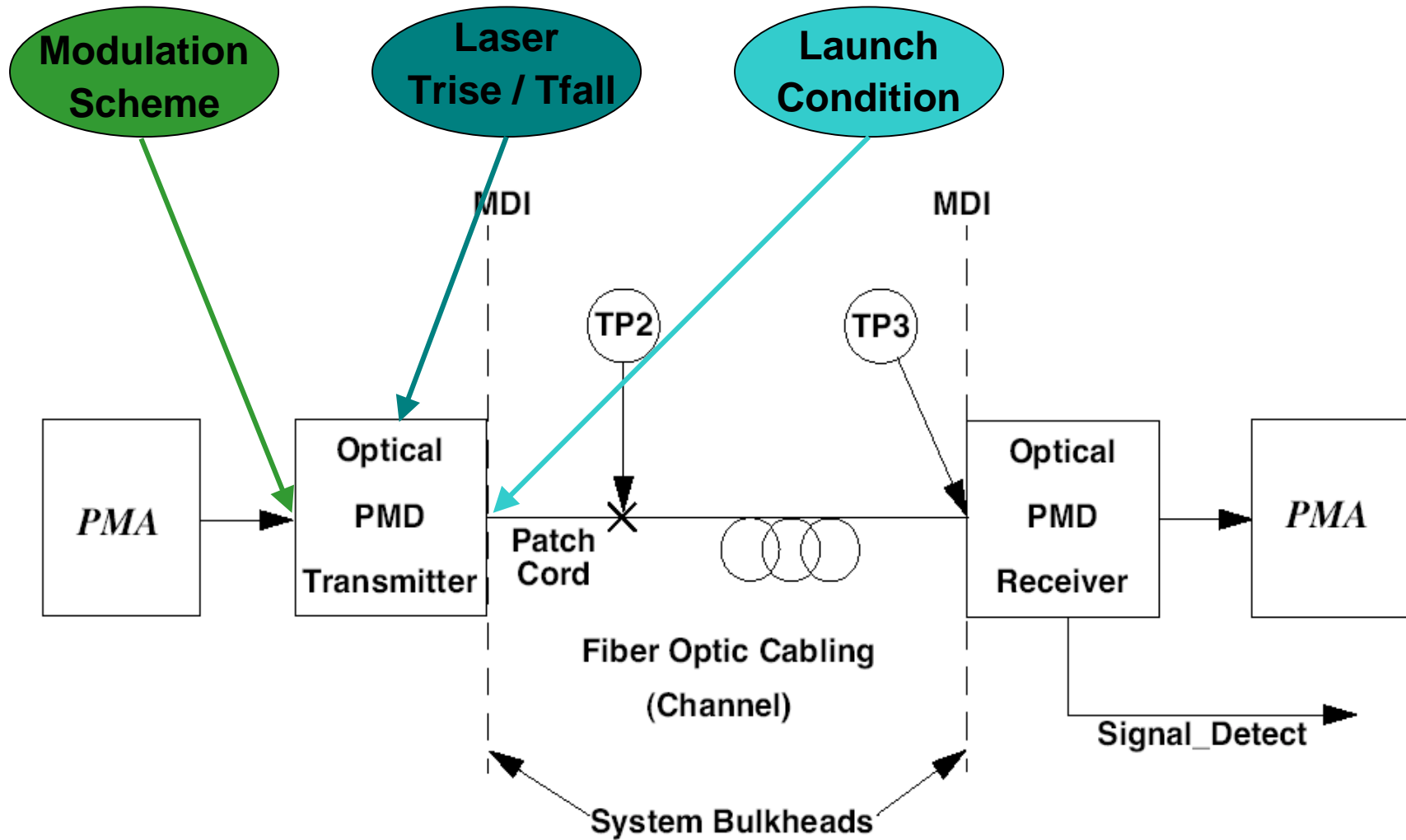
- Take the opportunity of creating a new PMD to address the highest cost areas:

Typical 10G Module Cost Distribution



- Once a module matures, the optical front end typically accounts for most of the cost
- Aggressive approach needed to reach 3 x $\{1000\text{Base-SX}\}$ for 300m applications
- $\{10\text{GBase-LR} + \text{EDC}\} \geq \{10\text{GBase-LR}\}$: Solution is NOT to simply add EDC to LR

Key Factors Impacting Transmitter Cost

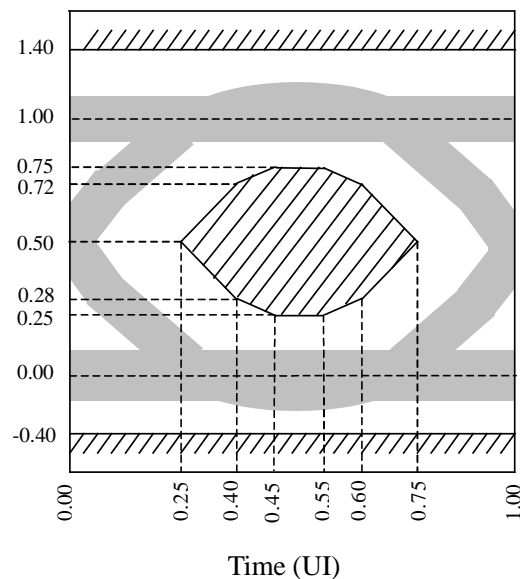


Launch Conditions to Consider

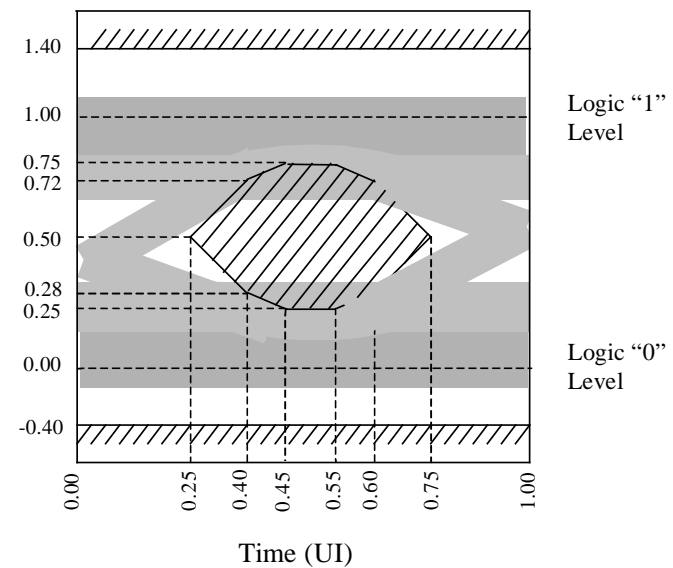
- Specify launch into multimode fiber only
 - No single mode fiber launch required
 - This will support lower cost TOSA's, but we sacrifice a common platform between 10GBASE-LR solution and the EDC PMD
- If offset launch is necessary, specify single condition for all MMF (62.5 μ m and 50 μ m)
 - Studies show optimal offset for 50 μ m and 62.5 μ m differ.
 - Optimal offsets: 50 μ m (7 to 17 μ m), 62.5 μ m (18 to 28 μ m)
 - Different conditions requiring different TOSAs will add cost
- Lowest cost solution: launch down the middle of the fiber and make full use of the core
 - Maximum possible alignment tolerance
 - Can EDC compensate for possible DMD?
 - What is the worst case OFL BW in this case?

Laser Response Requirements

- Relaxing the Laser rise and fall times will improve yields, however, the eye will begin to close at TP2
 - What can EDC live with?



10GBASE-LR



10GBASE-EDC

Effect of Transmit Specifications on Channel

- Relaxed transmit eye
 - Enables higher rise/fall time
 - Enables lower reference receiver bandwidth and lower relaxation oscillation frequency
 - Causes more channel (i.e. laser+fiber+optical receiver) ISI
- Relaxed launch conditions
 - Allow more DMD in fiber
 - Cause more channel ISI
- EDC compensates for increased channel ISI
 - Some increase in ISI penalty that must be accounted for

Modulation Scheme Choices

- Stay with NRZ
 - Can still relax transmitter specs, but must deal with increase in ISI penalty
- Consider multi-level modulation
 - Highest potential for reducing cost of optical packages and devices
 - Could enable using standard TO packaging technology versus the high speed packages we use today

SFP Style TOSA



High Speed/Temp TOSA

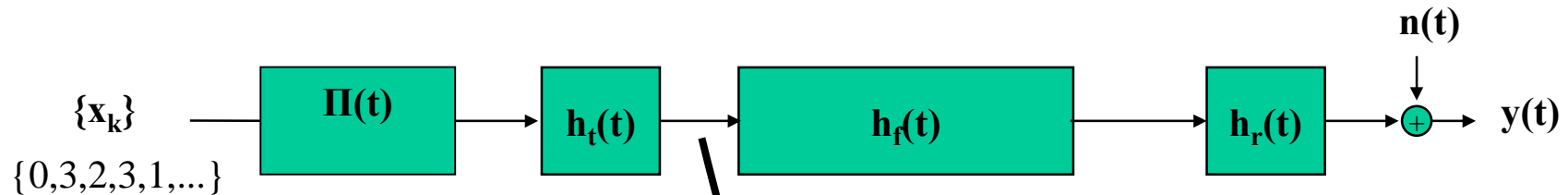
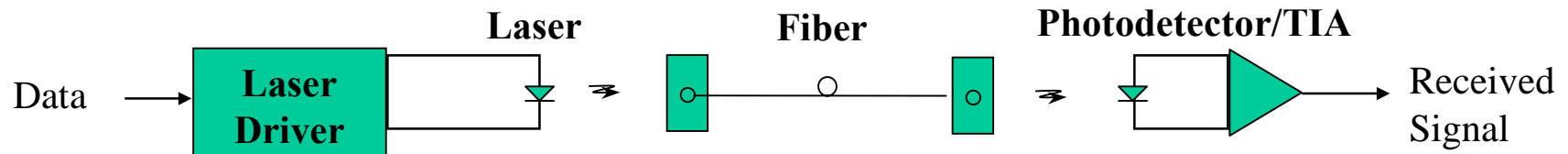


- Need to study impact of multilevel modulation on linearity requirements of optical devices, RIN penalties, modal noise penalties, etc.

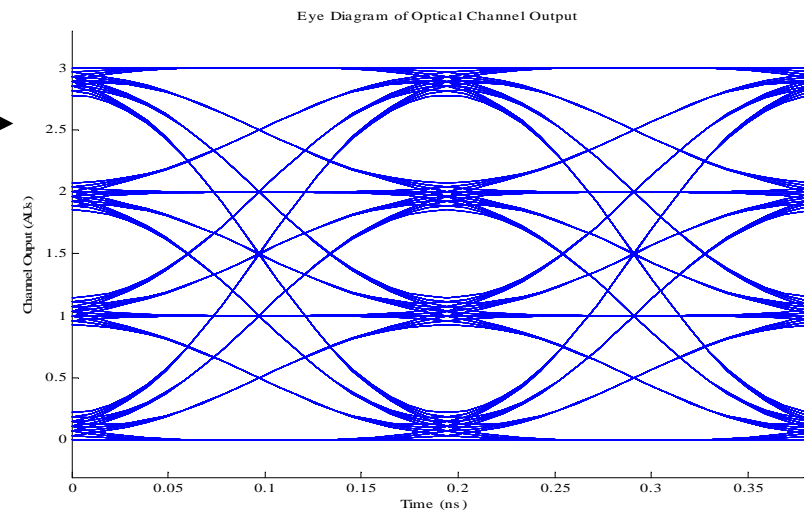
Simple Approach: PAM-4

- Motivation:
 - Works well with lower speed, lower cost optics
 - Well suited to severe ISI from 300m FDDI MMF
 - Enables significant increase in available power budget
- How it works
 - 4-level symbols, 2 bits per symbol
 - Symbol rate = 10.3125/2 Gbaud
 - No additional coding beyond 64/66 ==> no change to PCS; simple interface to PMD
 - Multilevel power penalty vs. NRZ? Actually, it's a gain:
 - 3x reduction in signal spacing ==> 4.8 dB power penalty
 - 2x reduction in baud rate ==> 1.5 dB reduction in RMS noise power
 - 2x reduction in baud rate ==> Varying reduction in ISI
 - For severe ISI channels, PAM4 has a net *gain* versus NRZ

PAM4 Channel Model

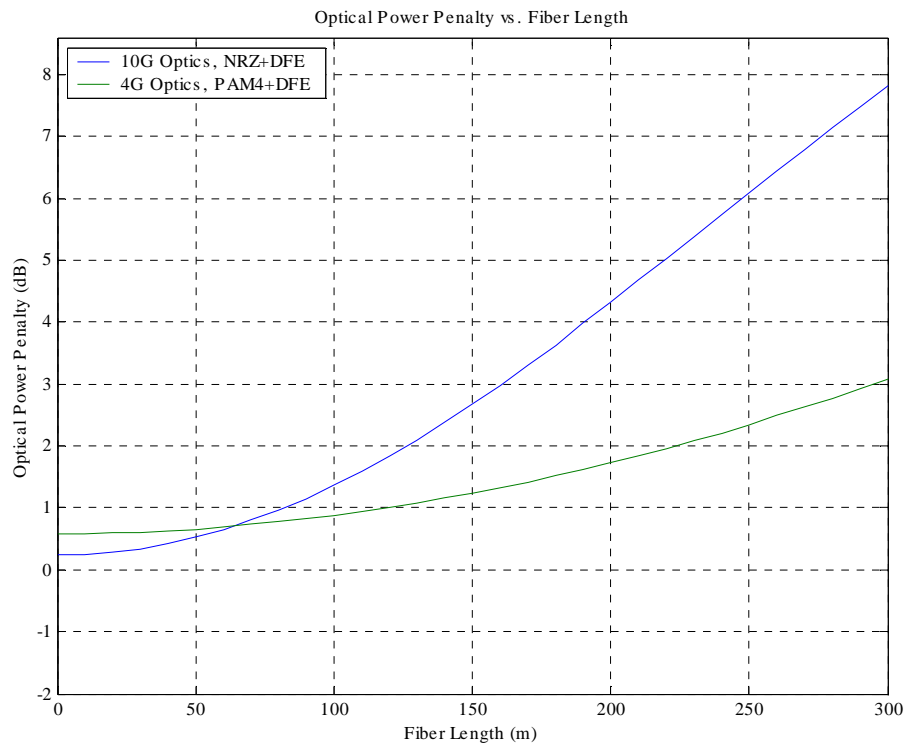


- Use same impulse responses as 802.3ae link model
 - Fiber: Gaussian model, modal BW = 500 MHz*km
- Transmit 4 levels instead of 2



Eye diagram shows 4G laser

PAM4 Performance



- Two cases:
 - 1. NRZ, 10G optics
 - 2. PAM4, 4G optics
 - Both use ideal DFE
- 10G optics specs from 10GBase-LR
- 4G optics specs from published data sheets
- Power penalty indicates receive OMA required for 10^{-12} BER, relative to 10GBase-LR receive sens.

PAM4 Performance (Cont.)

- Additional (> 4.5 dB) power budget provided by PAM4 at 300m can be used to
 - Operate over worse fiber
 - Relax launch requirements
 - Lower Tx power
- Issues for Further Study
 - Laser linearity
 - RIN
 - Modal noise
 - Compliance methods and specs

Summary

- Relaxing the mask at TP2 will improve yields and lower costs for optical module manufacturers
- EDC can and should enable such relaxation
- Relaxing specs possible with NRZ
- Even better cost and performance available with PAM4
- Media supported needs to be clearly defined in the EDC PAR
- Task Force should look at
 - Relaxed transmitter specs
 - PAM4