50 Gb/s per lane MMF objectives

IEEE 50G & NGOATH Study Group

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Jonathan King, Finisar

Contents

- Introduction
- Overview of technology options for 50 Gb/s per lane over MMF, and discussion
  - PAM4, NRZ, 2 λ
- Proposed objectives
  - 50 Gb/s and 200 Gb/s
  - 100 Gb/s

Introduction

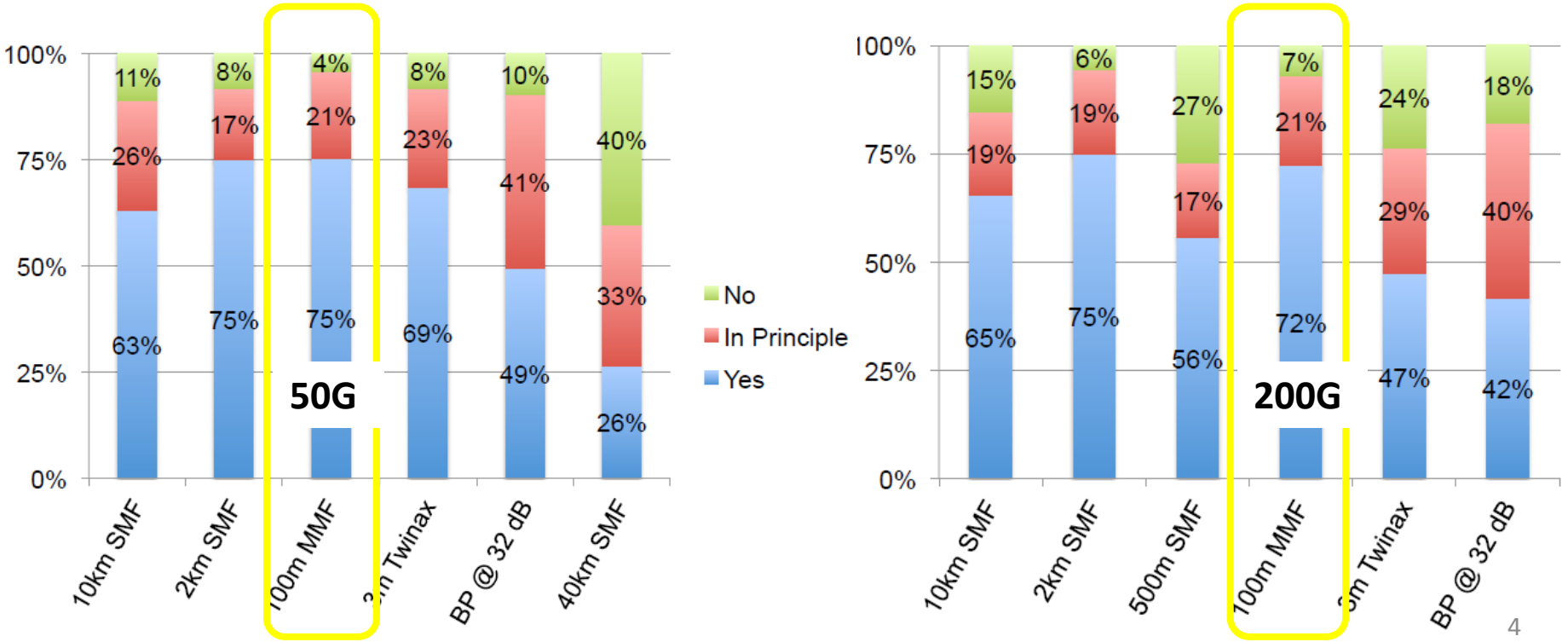
- For the 50 Gb/s single lane project, adding a 50 Gb/s over MMF objective will provide
  - server interconnect for end/middle of rack switch architecture
  - an upgrade path for single lane 25 Gb/s over MMF
  - … and is needed for all the good reasons that an objective for 25 Gb/s over MMF was included in P802.3by*
- Adding a 200 Gb/s four lane variant requires minor additional work and adds support for anticipated early breakout applications
- In the recent informal survey for the 50G & NGOATH study group, objectives for 50 Gb/s over MMF and 200 Gb/s over MMF both received strong support.**

* king_25GE_02_0914a.pdf

** nowell_010616_NGOATH_adhoc.pdf

Introduction: informal survey results

- From nowell_010616_NGOATH_adhoc.pdf
  - Straw poll on Survey Monkey gauging support for various potential 50G 100G and 200G objectives.
    - 75 respondents; Questions of form: "I support the adoption of < rate > Gb/s Ethernet objective for <reach> of <medium>".
  - Very strong support (">90%") for 50G and 200G (4 lanes of 50G) over MMF



Technology options and discussion

Technology options: 50 Gb/s per lane NRZ

- Needs very fast (~12 ps rise-fall time) transmitters, and (~40 GHz bandwidth) receivers ,
- Tough design space for 850 nm VCSELs
  - Worth looking at longer wavelengths, or radically new VCSEL structures, but this will be a long term development with substantial schedule & technology risk
- Probably limited to short reach (~50 m on OM4), even with strong FEC and equalization
  - Several papers by Dan Kuchta, IBM, for example:
    - D. M. Kuchta, et al, "64Gb/s Transmission over 57m MMF using an NRZ Modulated 850nm VCSEL," OFC, Mar. 2014

Technology: 50 Gb/s per lane PAM4 with VCSELs

- Compared to NRZ, a PAM4 modulation format consumes 5 dB of optical link budget and is
  - more sensitive to RIN
  - needs strong FEC at any reach
  - needs Tx equalization, Rx equalization, linear TIA
- … but looks like a nearer term development:
  - an evolution of current 25 G VCSEL and receiver optics to manage RIN and increase link budget
  - substantial re-use of transmitter and receiver electronics, developed for 50Gb/s PAM4 over SMF
  - adapt Tx and Rx quality metrics for SMF being developed in P802.3bs
- 100 m over OM4 appears achievable
- Potentially compatible with SFP28 form factors
  - four lane variants compatible with QSFP28 form factors

Other technology options: SWDM

- 2 x 25 Gb/s NRZ, (2 λ) bi- or co-directional
- Low technical risk for optics
- 50G single electrical lane input would need reverse gearbox (1:2) inside the module
- Two VSCELs per direction means skew must be managed when reconstructing the electrical output.
- 'Two of everything'
  - Not the lowest long term cost or power
  - Form factor compatibility ?

50Gb/s PAM4 over MMF publications

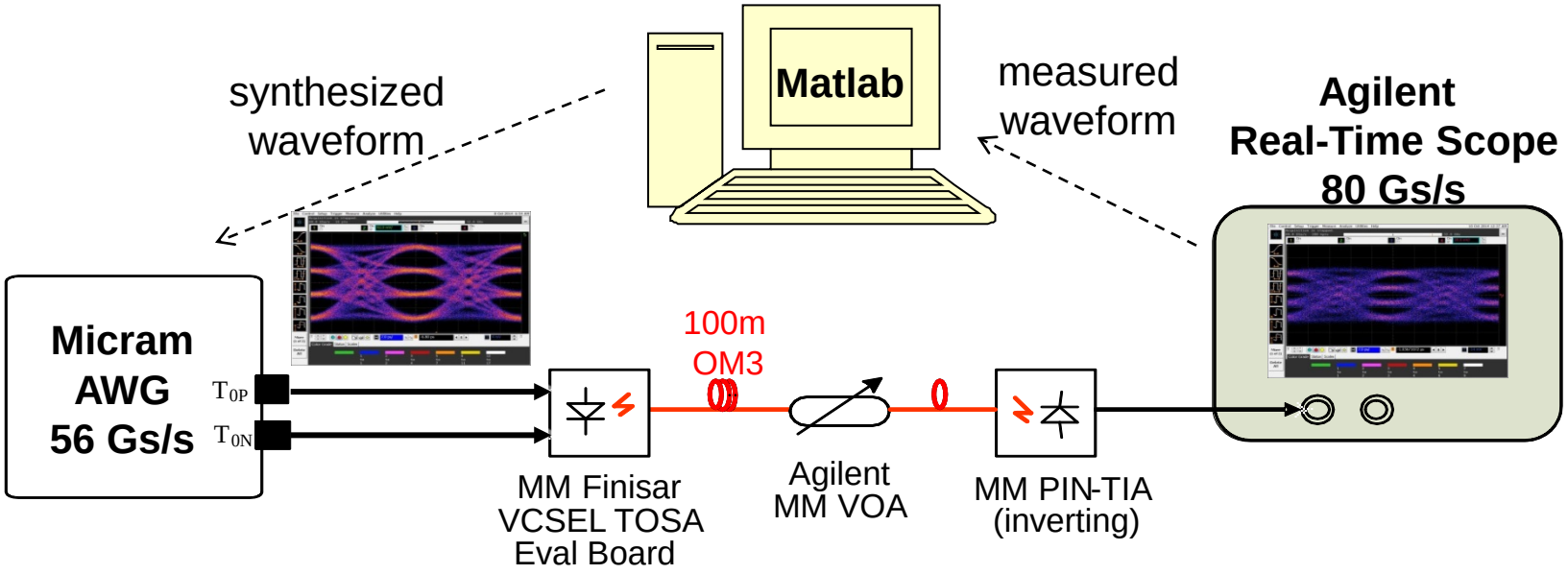
Several papers on PAM4 with VCSELs at 50 Gb/s lane rates due to be presented at OFC 2016, including:

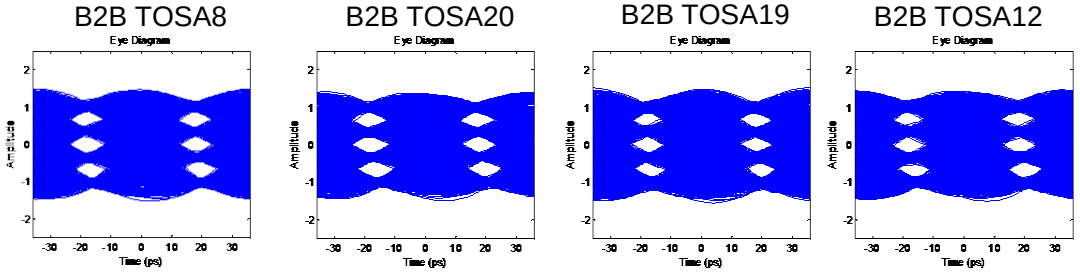
- "51.56 Gb/s SWDM PAM4 Transmission over Next Generation Wide Band Multimode Fiber"
- "180 Gb/s PAM4 VCSEL transmission over 300m Wideband OM4 Fibre", R Motaghian, et al Finisar and F Achten et al, Prysmian Group
- "200m 2x50 Gb/s PAM-4 SWDM Transmission Over Wideband Multimode Fiber using VCSELs and Pre-distortion Signaling"

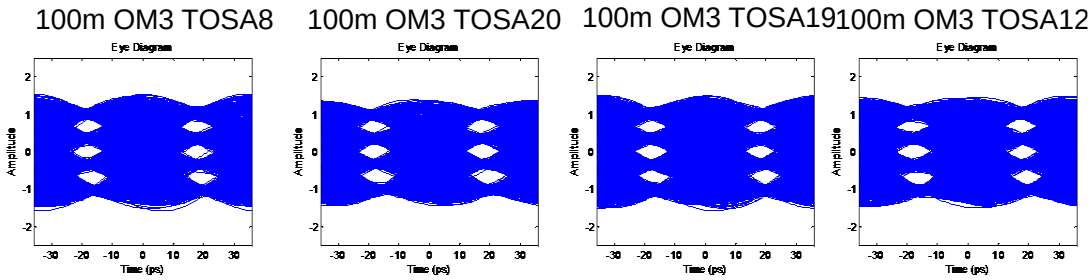
Previously published

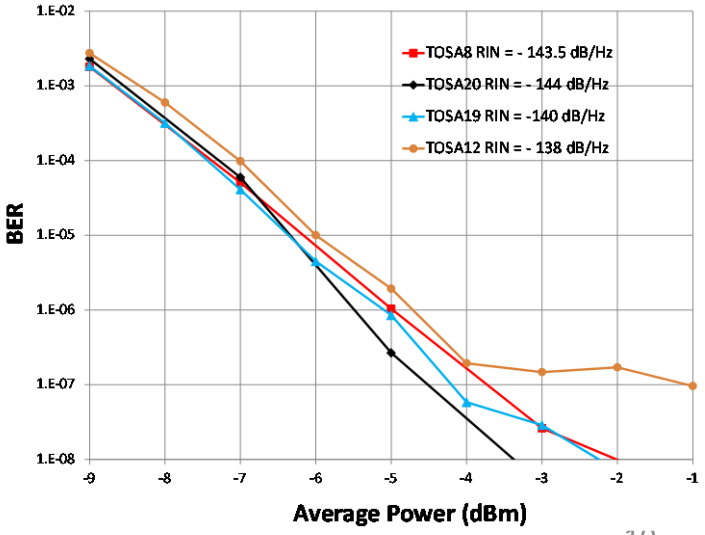
- J. Castro, et al, "50 Gb/s 4-PAM over 200m of High Bandwidth MMF using a 850nm VCSEL", OFC 2015.
- K. Szczerba, et al, "70 Gb/s 4-PAM and 56 Gb/s 8-PAM using an 850 nm VCSEL," JLT.vol 33(7) 2015.

Technical feasibility – 56 Gb/s PAM4 work at Finisar - 2





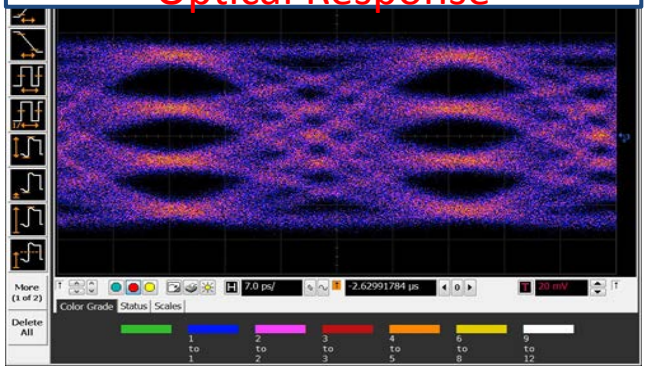




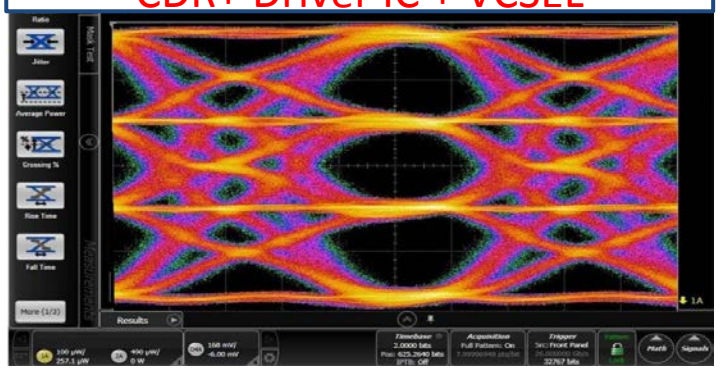
Technical feasibility – 50 Gb/s PAM4 work at Finisar -1

Bench top PAM4 experiments using 25Gb/s VCSELs

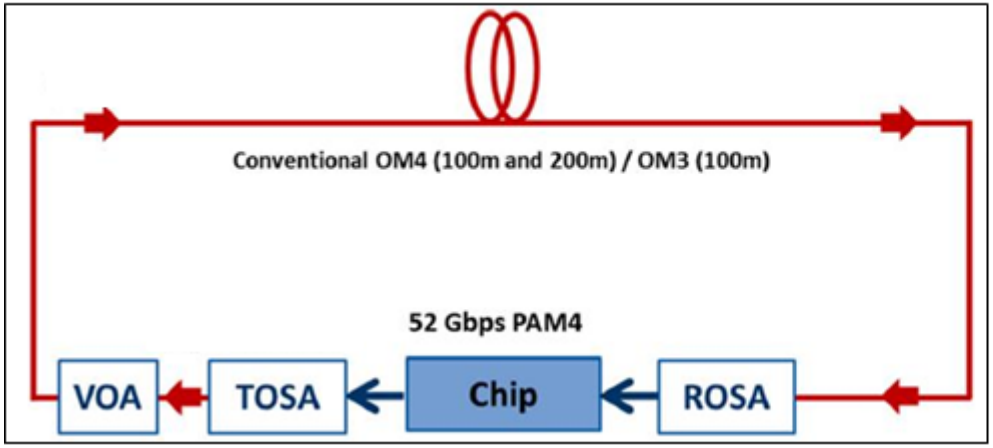
50Gb/s AWG + VCSEL
Optical Response

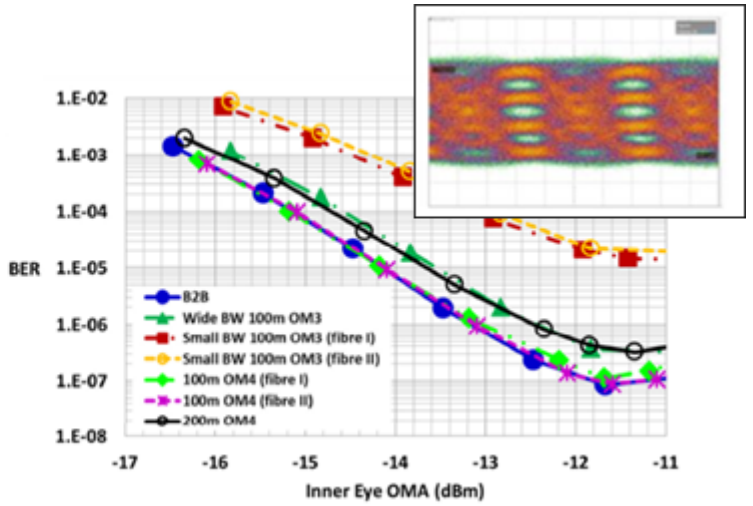


50Gb/s PAM4 Optical Response
CDR+ Driver IC + VCSEL



and early PAM4 PHY evaluation….

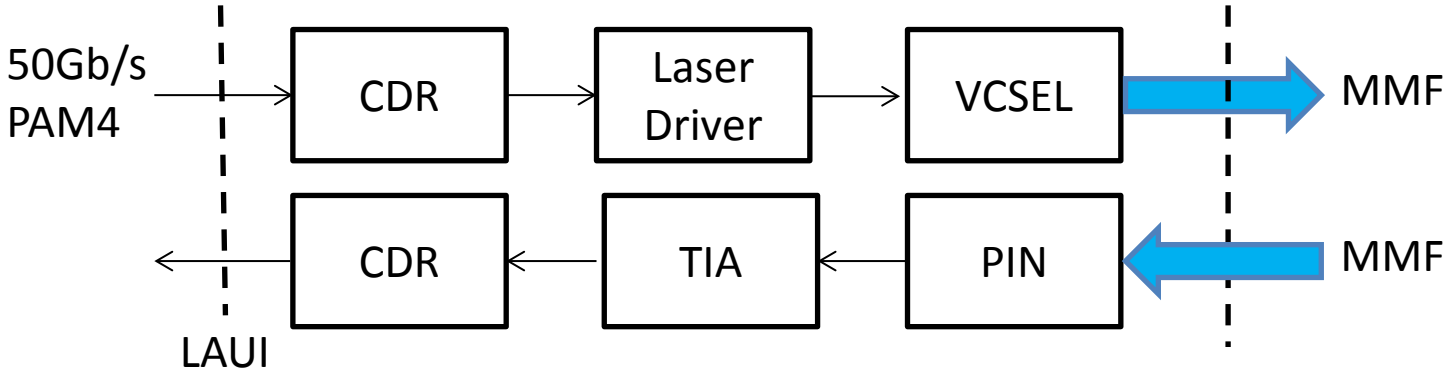




50 Gb/s PAM4 optical lanes for MMF

- 50 Gb/s PAM4 modulation format with 850 nm VCSELs, single optical and electrical lane per direction
- Retimed Tx and Rx
- Equalization in Tx and Rx chains
- FEC supported (RS-544)

  Example parameters next slide



Example parameters for 50Gb/s PAM4 over MMF

Transmitter (850 nm VCSEL)	**Value**	**Units**	**Notes**
Wavelength range	840 to 860	nm	
Spectral width	0.6	nm	
Tx_OMA min at max TDP	-1	dBm	outer eye*
Tx_OMA-TDP	-5	dBm	outer eye
TDP max	4	dB	with Ref EQ**
ER min	4	dB	model input
$T_{r\text{-}f}$	18	ps	20-80%, model input ***
RIN	-138	dB_c/Hz	model input
Link			
Insertion loss, max inc. 1.5 dB connector loss	1.9	dB	100m OM4
Receiver			
Bw	21.25	GHz	0.8 x symbol rate, model input
Nominal USRS, OMA max	-6.9	dBm	at BER = 2.4 x 10^{-4}, model input
SRS, OMA max	-3.0	dBm	outer eye

For this example: estimated RIN penalty ~2 dB, ISI penalty ~2.2 dB; total penalty ~5.1 dB (before EQ).

* Outer eye, measured with slow square wave pattern: e.g. eight '00', eight '11'

** Possible reference equalizer is a 5 tap T/2 FFE or equivalent

*** Effective rise-fall time (combination of VCSEL and equalizing Tx driver)

Concluding remarks

- An objective for a 50 Gb/s PMD for operation over MMF could be met with several technology approaches.
- 50 Gb/s PAM4 using 850nm VCSELs offers:
  - an evolution of current 25 G VCSEL and receiver optics, to manage RIN and increase link budget.
  - substantial re-use of transmitter and receiver electronics, developed for 50Gb/s PAM4 over SMF
  - substantial re-use of the Tx and Rx quality metrics for SMF under development in P802.3bs
  - substantial amount of work from several groups showing technical feasibility
- 100 m on OM4 appears achievable
- Potentially compatible with SFP28 form factors
  - four lane variants compatible with QSFP28 form factors

Proposed 50G and 200G MMF objectives

- Provide physical layer specifications which support:
  - single lane 50 Gb/s operation over at least 100 m over MMF
  - four lane 200 Gb/s operation over at least 100 m over MMF

Possible 100 G over MMF

- Also under consideration in this study group, is the formation of a 100 G project.
- If objectives for 50 G and 200 G over MMF are adopted, then the addition of a 100 G over MMF objective (based on two lanes of 50 G) would be negligible additional work.

Possible 100G MMF objective

- Provide physical layer specifications which support 100 Gb/s dual lane operation over at least 100 m over MMF.

Q & A

Thanks !