Lower fibre count 200 Gb/s and 400 Gb/s PMDs

NGMMF study group meeting

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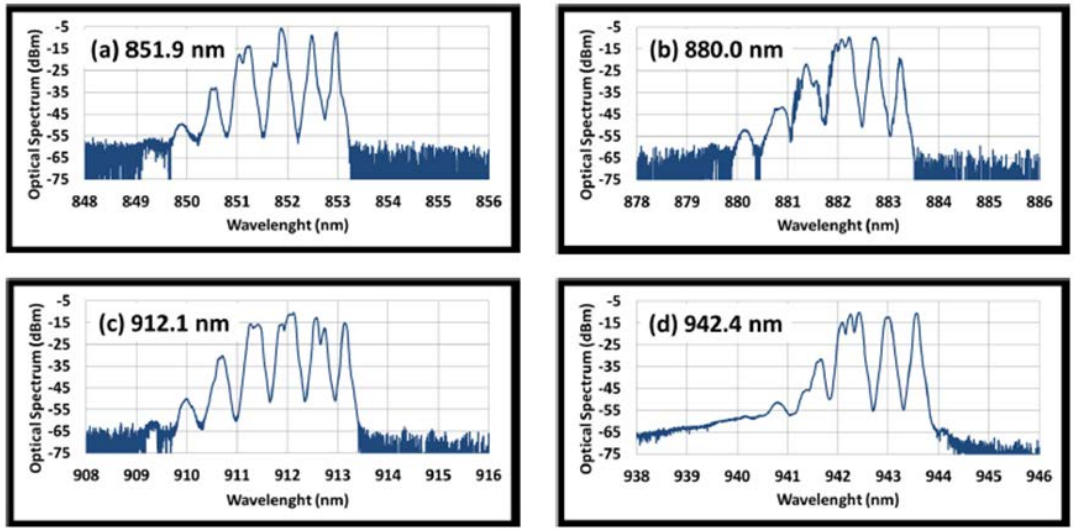
Jonathan King, Finisar

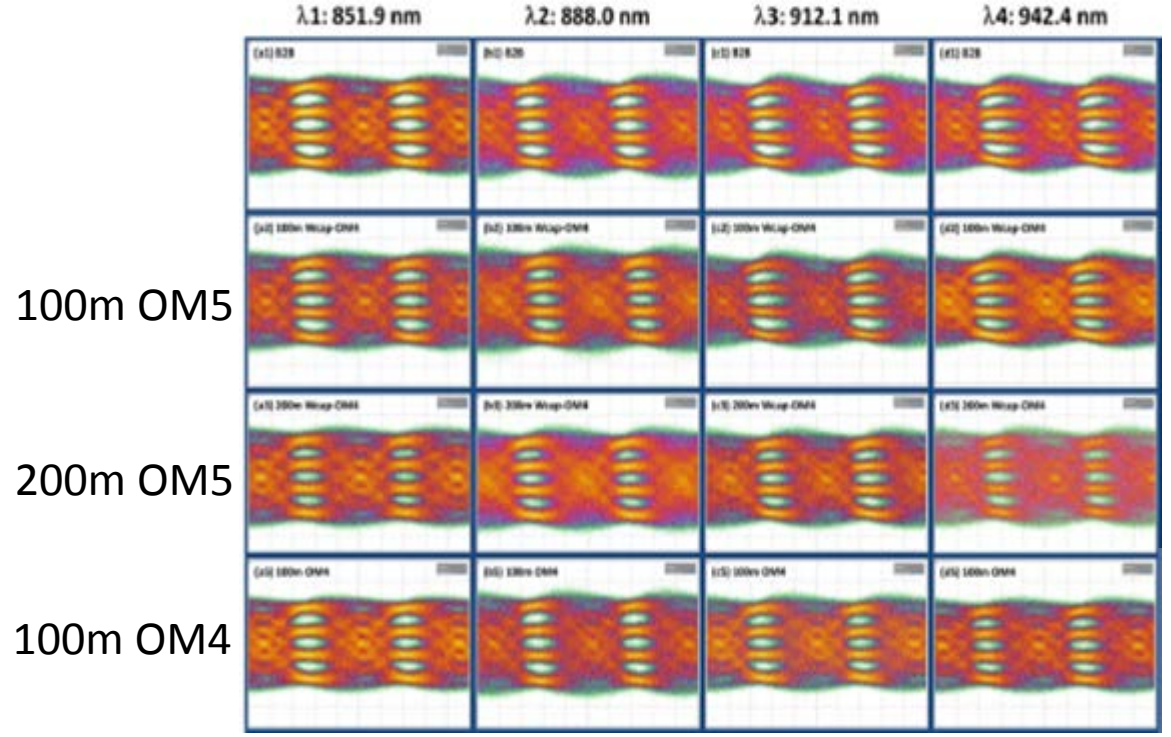
Technologies: electrical interface, 50Gb/s PAM4 VCSELs, SWDM

- Re-use 50Gb/s PAM4 signaling and electrical interfaces from 802.3cd
  - same PCS, PMA, FEC, 400GAUI-8 or 200GAUI-4
  - ideally use same electrical port as 400GBASE-FR8, 400GBASE-LR8, 400GBASE-DR4
  - potentially compatible with QSFP-DD form factor
- Leverage specifications and definitions from 802.3cd (draft 3.0) for 50GBASE-SR, 100GBASE-SR2 and 200GBASE-SR4
- 50 Gb/s PAM4 VCSELs: Many examples of published work, combined with shortwave wavelength division multiplexing (SWDM), have been published. Adding more wavelengths (2, 4 or 8) can trade off against reach, but is feasible. There's an excellent summary in parsons_3cd_01_0118
- 100 Gb/s PAM4 VCSELs: some hero experiments, very strong FEC and/or complex modulation schemes
- SWDM: existing 40Gb/s and 100Gb/s VCSEL based products using 2 and 4 wavelengths; mux/demux loss ~ 2 dB per end
- *High speed VCSELs at multiple wavelengths are an established technology*

Multiple wavelength VCSELs examples

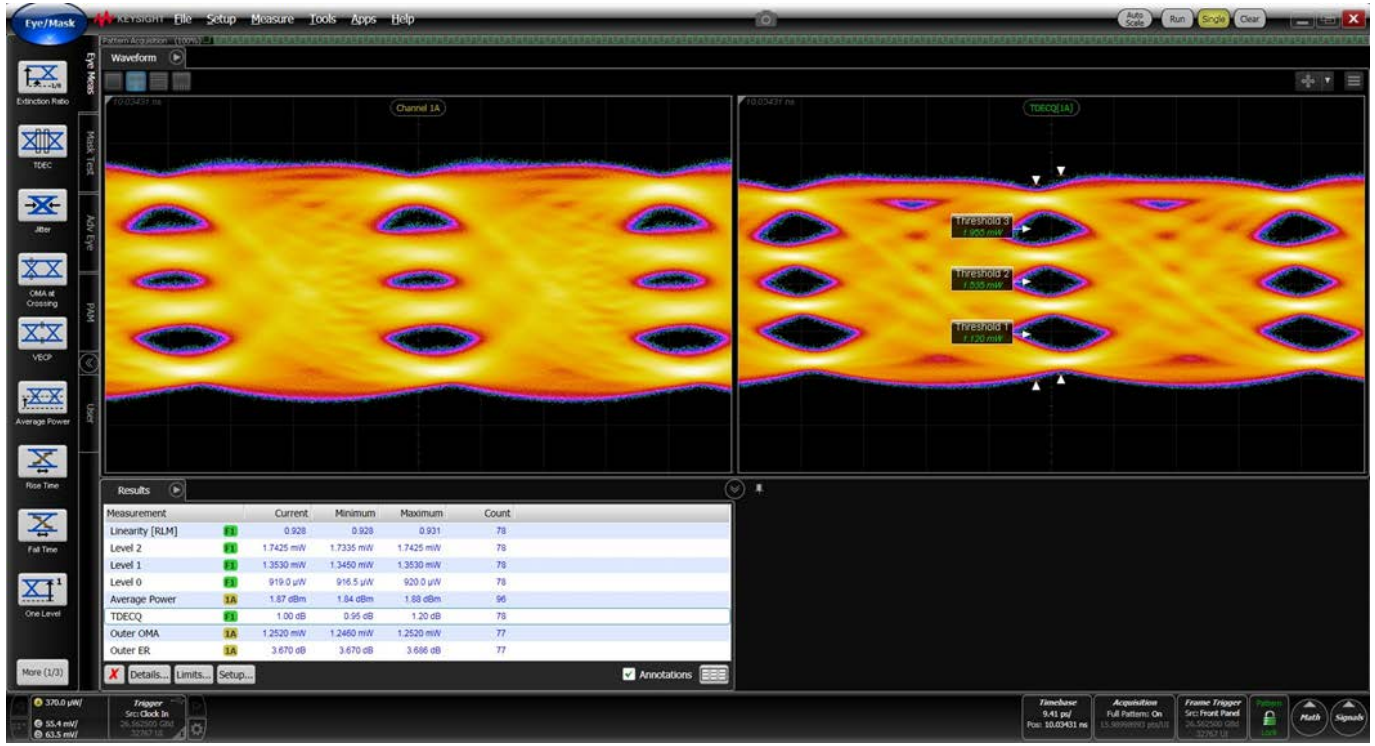


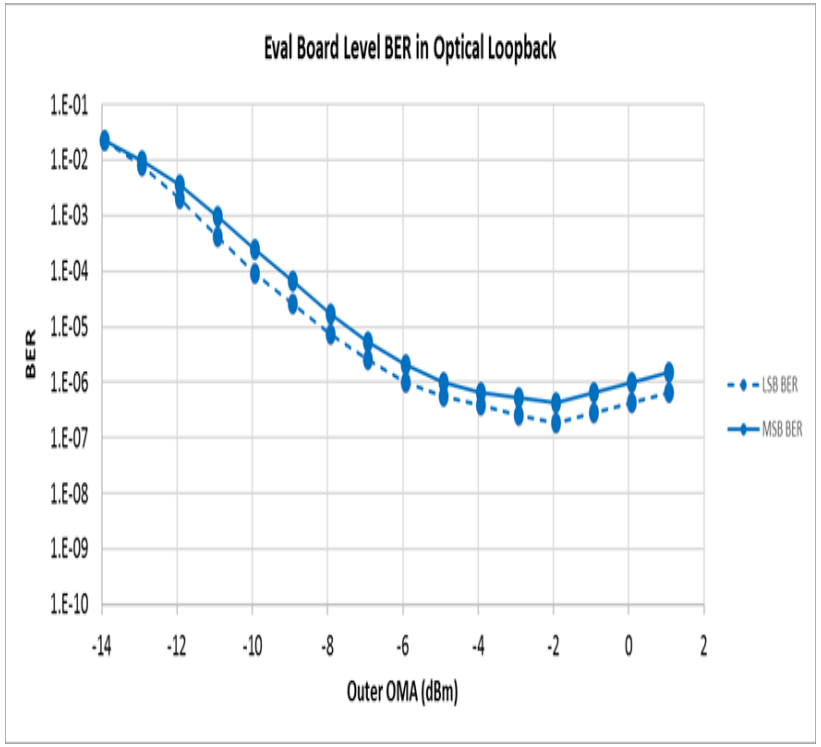
- RMS spectral bandwidths (SBWs) : 0.558, 0.370, 0.5011, and 0.527nm
- The measured RIN OMAs were ~-137 dB/Hz.



- Spectra and eyes for nominal 850, 880, 910 and 940 nm VCSELs
  - eyes shown at ~23 GBaud, limited by the test equipment at that time.
  - 100m over OM4 looks feasible (consistent with 802.3 reach over MMF)

Recent evaluation board level integration of 56Gb/s PAM4 driver, VCSEL, and receiver/TIA and EQ/CDR





- SECQ = 1.0 dB; back-to-back sensitivity ~-10 dBm (for 1.0 dB SECQ Tx)

Enhanced link budgets to accommodate SWDM mux/demux losses within PAM4 link budgets

- Improved launch optics for PAM4 VCSELs
  - Better reflection tolerance – lower RIN
  - Breaks correlation between VCSEL wavelength modes and coupled fibre modes
  - Higher launch power capability equates to
- Improved receiver optics for PAM4 over MMF
  - Coupling and responsivity improvements
  - Lower input-referred noise, linear TIA designs, EQ

400 Gb/s PMDs

Current 400GBASE-SR16: 16 fibres per direction – not broadly adopted

- Fibre intensive, not compatible with current cabling practices
- Used in early 400G system bring-up and test; was available at least a year before SMF, but now LR8 is available, it has been supplanted

Potential new PMDs

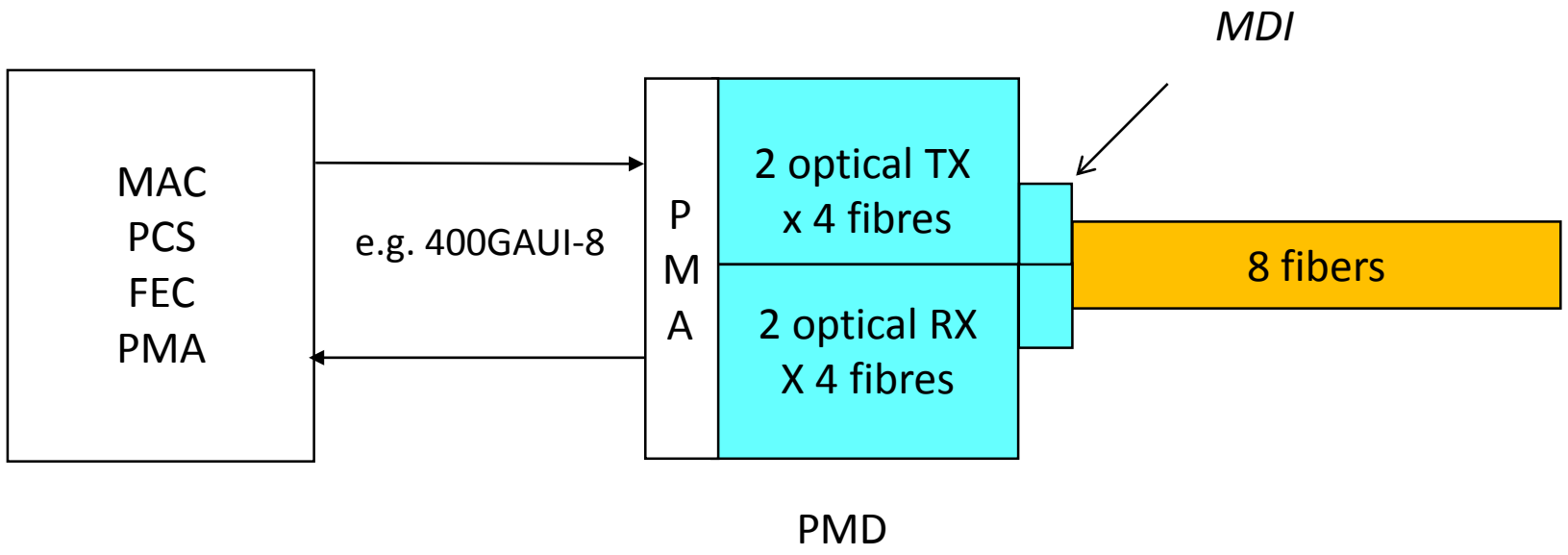
- 400GBASE-SR8: 8 fibres per direction, 1 wavelength per fibre, 50 Gb/s PAM4 per wavelength
  - Not compatible with current cabling practices
- 400GBASE-SR4.2: 4 fibres per direction, 2 wavelengths per fibre, 50 Gb/s PAM4 per wavelength
  - Compatible with current 4 pair MMF cabling practices
  - 40GBASE-SR4, 100GBASE-SR4, 200GBASE-SR4
- 400GBASE-SR4: 4 fibres per direction, 1 wavelength per direction, 100 Gb/s PAM4 per wavelength
  - Probably premature - a few 100 Gb/s papers report ‘hero’ results with very strong FEC or complex modulation schemes
- 400GBASE-SR1.8: 1 fibre per direction, 8 wavelengths per fibre
  - Compatible with current duplex MMF cabling practices

200 Gb/s PMD

- 200GBASE-SR4 requires 4 fibres per direction
- 200GBASE-SR1.4 requires 1 fibre per direction
  - 1 fibre per direction, 4 wavelengths per fibre, 50 Gb/s PAM4 per wavelength
  - Compatible with current duplex MMF cabling practices
  - Point to point 200 Gb/s link with significantly lower cost than 200GBASE-SR4
- Re-use signaling and electrical interfaces from 802.3cd
  - same PCS, PMA, FEC, 200GAUI-4
  - same electrical port as 200GBASE-SR4, -DR4, -FR4, -LR4
  - potentially compatible with QSFP form factor

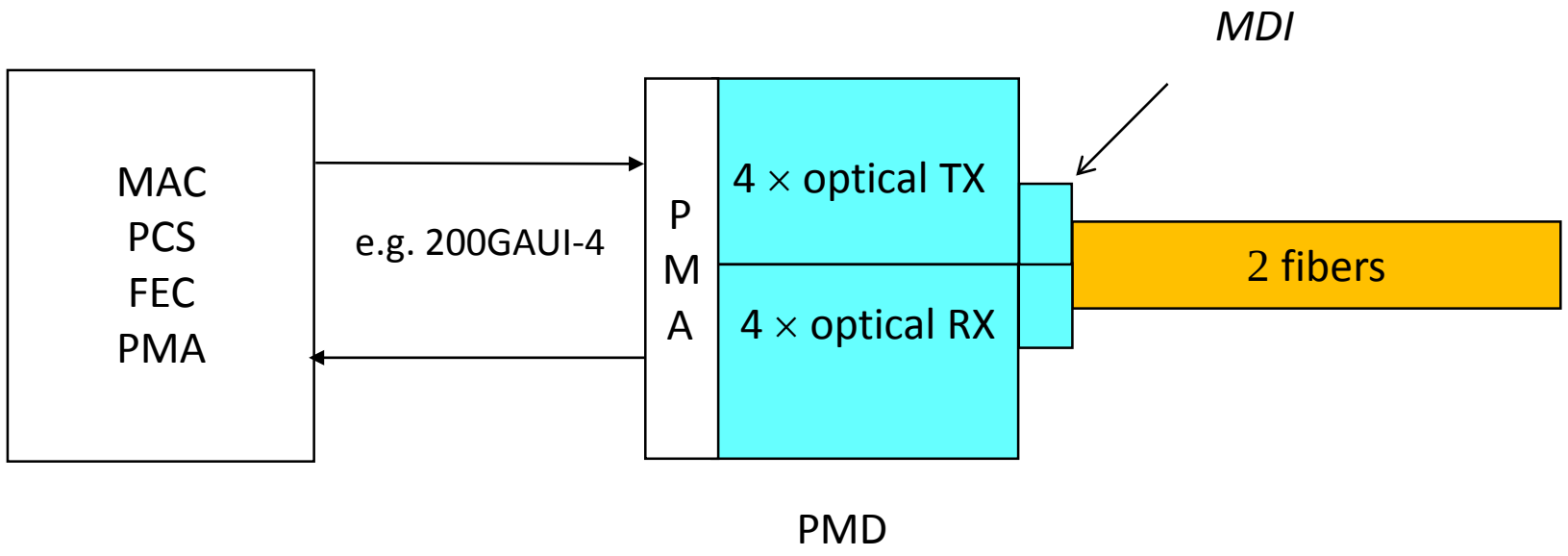
Potential proposal for 400GBASE-SR4.2

- Two optical lanes per fibre, four fibres per direction for 400GBASE-SR
- Each lane @ 26.5625 GBd PAM4 over 100 m OM4 fiber.
  - Signaling rate assumes same FEC as 200GBASE-SR4
  - Target BER (prior to error correction) around 2.4×10^{-4} and random error statistics
- 850 nm and 880 nm sources and receivers



Potential proposal for 200GBASE-SR1.4

- Four optical lanes per fibre per direction
- Each lane @ 26.5625 GBd PAM4 over 100 m OM4 fiber.
  - signaling rate assumes same FEC as 200GBASE-SR4
- 850 – 940 nm sources and receivers
  - Assumes target BER (prior to error correction) around 2.4×10^{-4} and random error statistics



Concluding remarks

- 50 Gb/s PAM4 modulation on VCSELs and SWDM are established technologies which are already used in emerging products
- Combining them enables lower cost, reduced fibre-count, PMDs such as
  - 200 Gb/s over a single pair MMF cabling
  - 400 Gb/s over 1 or 4 pair MMF cabling