# Baseline proposal for the 100 Gb/s MMF objective using two-wavelength PAM4 modulation

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# Adopted MMF objectives

- Define a single-lane 50 Gb/s PHY for operation over MMF with lengths up to at least 100 m

- Define a two-lane 100 Gb/s PHY for operation over MMF with lengths up to at least 100 m

- Define 200 Gb/s PHYs for operation over MMF with lengths up to at least 100 m

# Motivation

- Broad market potential for a duplex MMF solution at 100 Gb/s
- Technical feasibility of FEC-supported 26.5625 GBd PAM4 modulation demonstrated using uncooled VCSELs, building on NRZ electronics and optoelectronics developed for 25 Gb/s lanes in multiple 802.3 and T11 standards
- Large industry investment in multimode WDM in recent years, evidenced by: (i) field-proven products such as Cisco 40G Bi-Di; (ii) 100 Gb/s demonstrations by multiple vendors at OFC and ECOC; (iii) formation of SWDM Alliance to encourage adoption of cost-effective solutions for duplex MMF

# Motivation (cont.)

- A two fibers per direction solution is unconventional and poorly matched to the requirements of typical cabling installations
- Transceiver cost for a two wavelengths per direction solution is expected to be similar to a two fibers per direction solution
- A two wavelengths per direction solution provides a compelling route to a future 400 Gb/s PMD based on four fibers per direction
- Maintains the attractiveness of MMF cabling infrastructure

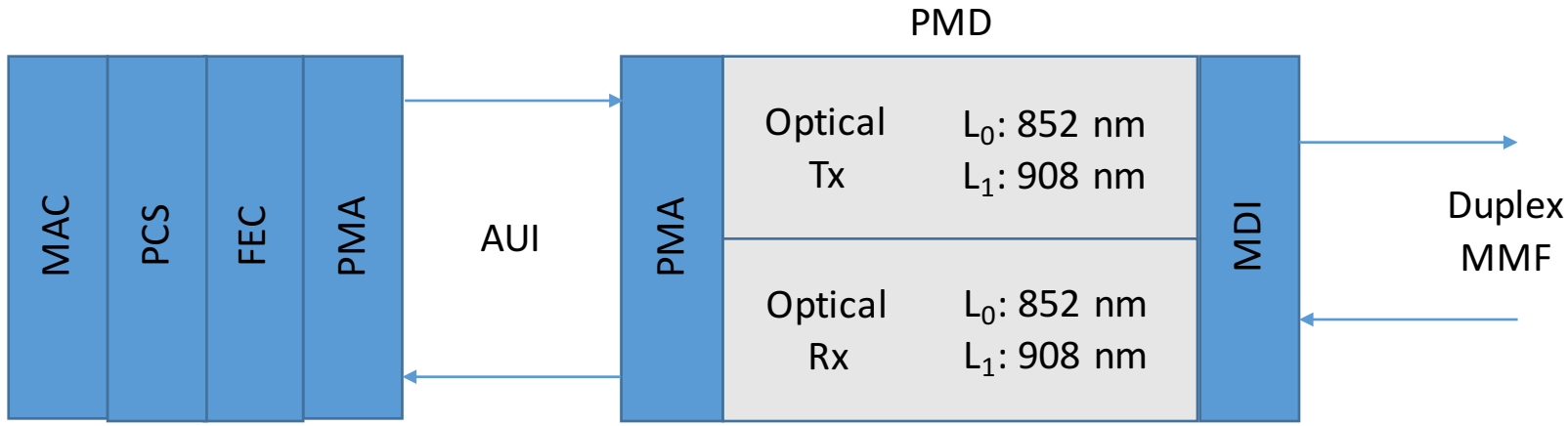
# OM3 & OM4 MMF performance beyond 860 nm

- Guidance from fiber manufacturers has been received regarding performance of OM3 and OM4 MMF in the 900 nm to 916 nm wavelength range

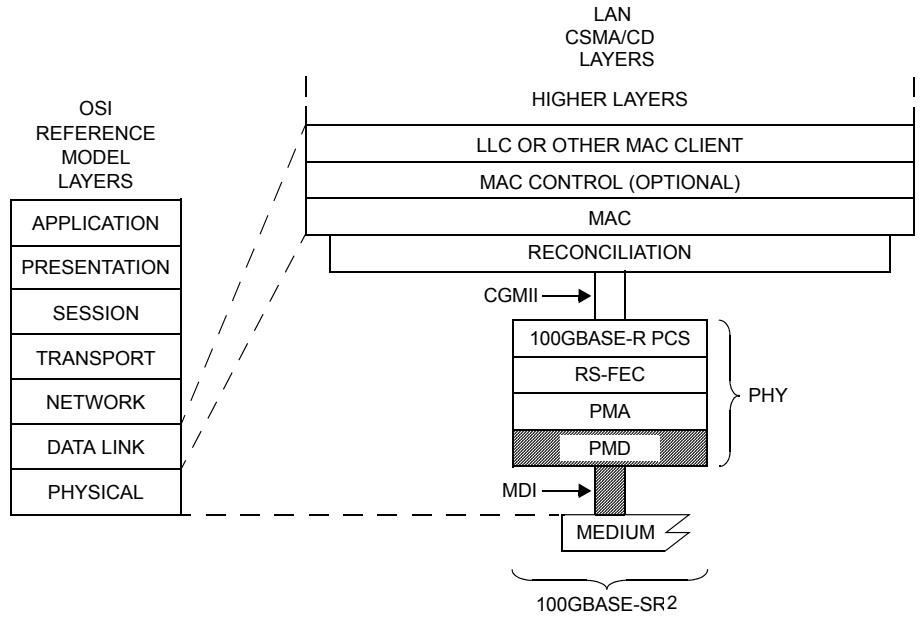
- Field-proven WDM products exist using OM3 and OM4 MMF with transmission in the 900 nm to 916 nm range

# Baseline proposal for 100GBASE-SR2

- Co-directional WDM transmission (with center wavelengths of 852 nm for $L_0$ and 908 nm for $L_1$) over 70 m OM3 and 100 m OM4
- If the project chooses RS(544, 514) FEC, then for each lane: 26.5625 GBd PAM4 modulation with pre-FEC BER target of $2.4 \times 10^{-4}$



# Position in 802.3 architecture




CGMII = 100 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER
PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FORWARD ERROR CORRECTION
SR = PMD FOR MULTIMODE FIBER

# WDM lane assignments

| Lane | Center wavelength | Wavelength range |
|---|---|---|
| $L_0$ | 852 nm | 844 nm to 860 nm |
| $L_1$ | 908 nm | 900 nm to 916 nm |

# Transmit characteristics

| Description | Value | Unit |
|---|---|---|
| Signaling rate, each lane (range) | 26.5625 ± 100 ppm | GBd |
| Lane wavelength range: lane $L_0$ | 844 to 860 | nm |
| lane $L_1$ | 900 to 916 | nm |
| Modulation format | PAM4 | |
| RMS spectral width | 0.6 | nm |
| Total average launch power (max) | +6.5 | dBm |
| Average launch power, each lane (max) | +3.5 | dBm |
| Average launch power, each lane (min) | -5 | dBm |
| $OMA_{outer}$, each lane (max) | +3 | dBm |
| $OMA_{outer}$, each lane (min)[a] | -3 TBC | dBm |
| $OMA_{outer}$ – TDECQ, each lane (min) | -4 TBC | dBm |
| TDECQ, each lane (max) | 4 TBC | dB |
| Average launch power of OFF transmitter, each lane (max) | -30 | dBm |
| Extinction ratio (min) | 3 | dB |
| Encircled flux | ≥ 86% @ 19 μm, ≤ 30% @ 4.5 μm | |

Transmit characteristics are at TP2
TDECQ is under development in P802.3bs for SMF PMDs; TDECQ configuration (including reference receiver) for MMF PMDs is TBD
[a] Even if TDECQ < 1 dB, $OMA_{outer}$ must be at least this value

# Receive characteristics

| Description | Value | Unit |
|---|---|---|
| Signaling rate, each lane (range) | 26.5625 ± 100 ppm | GBd |
| Lane wavelength range: lane $L_0$ | 844 to 860 | nm |
| lane $L_1$ | 900 to 916 | nm |
| Modulation format | PAM4 | |
| Damage threshold (min) | +7.5 | dBm |
| Average receive power, each lane (max) | +3.5 | dBm |
| Average receive power, each lane (min) | -6.9 | dBm |
| Receive power, each lane ($OMA_{outer}$) (max) | +3 | dBm |
| Receiver reflectance (max) | -12 | dB |
| Stressed receiver sensitivity, each lane ($OMA_{outer}$) (max) | -1.9 TBC | dBm |
| Receiver sensitivity, each lane (OMAouter) (max)[a] | -6 TBC | dBm |
| Conditions of stressed receiver sensitivity test: | | |
| Stressed eye closure (SECQ), lane under test | 4 TBC | dB |
| OMA of each aggressor lane | +3 | dBm |

Receive characteristics are at TP3
TDECQ and SECQ are under development in P802.3bs for SMF PMDs; TDECQ and SECQ configuration (including reference receiver) for MMF PMDs is TBD
[a] Receiver sensitivity is informative

# Illustrative link power budget (850 nm)

| Parameter | OM3 | OM4 | Unit |
|---|---|---|---|
| Effective modal bandwidth at 850 nm | 2000 | 4700 | MHz km |
| Power budget for max TDECQ | 6 | 6 | dB |
| Operating distance | 70 | 100 | m |
| Channel insertion loss | 1.8 | 1.9 | dB |
| Allocation for penalties (for max TDECQ) | 4.1 TBC | 4.1 TBC | dB |
| Additional insertion loss allowed | 0.1 | 0 | dB |

# Illustrative link power budget (916 nm)

| Parameter | OM3 | OM4 | Unit |
|---|---|---|---|
| Effective modal bandwidth at 916 nm | 1400 | 1900 | MHz km |
| Power budget for max TDECQ | 6 | 6 | dB |
| Operating distance | 70 | 100 | m |
| Channel insertion loss | 1.7 | 1.8 | dB |
| Allocation for penalties (for max TDECQ) | 4.1 TBC | 4.1 TBC | dB |
| Additional insertion loss allowed | 0.2 | 0.1 | dB |

# Conclusions

- Baseline proposal for 100GBASE-SR2 based on FEC-supported 26.5625 GBd PAM4 modulation
- Two wavelengths per direction allows support of duplex MMF with broad market potential
- FEC-supported 26.5625 GBd PAM4 approach is re-used from proposed 50GBASE-SR and 200GBASE-SR4, facilitating easy standardization, using same metrics, e.g. TDECQ
- Builds on substantial industry investment in multimode WDM by multiple vendors
- OM3 & OM4 MMF performance at the proposed wavelengths is field proven
- Provides a path to a future four-fiber 400 Gb/s PMD