400 Gb/s 100 m MMF reach objective draft baseline proposal

MMF ad hoc

IEEE P802.3bs, San Antonio, TX, Nov 2014

Outline

- Baseline proposal of a retimed PMD to address the 802.3bs objective to 'Provide physical layer specifications which support link distances of at least 100 m over MMF'
  - 16 lane parallel, short wavelength based PMD for 400GBASE-SR16.
  - Leveraging 100GBASE-SR4 technology, compatible with 16 x 25 Gb/s electrical interface, and breakout applications.
  - Assumed use of 100GBASE-SR4 FEC, or similar strength FEC (to be defined in 802.3bs), to enable 100 m reach.
  - Architecture, parameters and specifications for optical interfaces, and the proposed MDI, follow.

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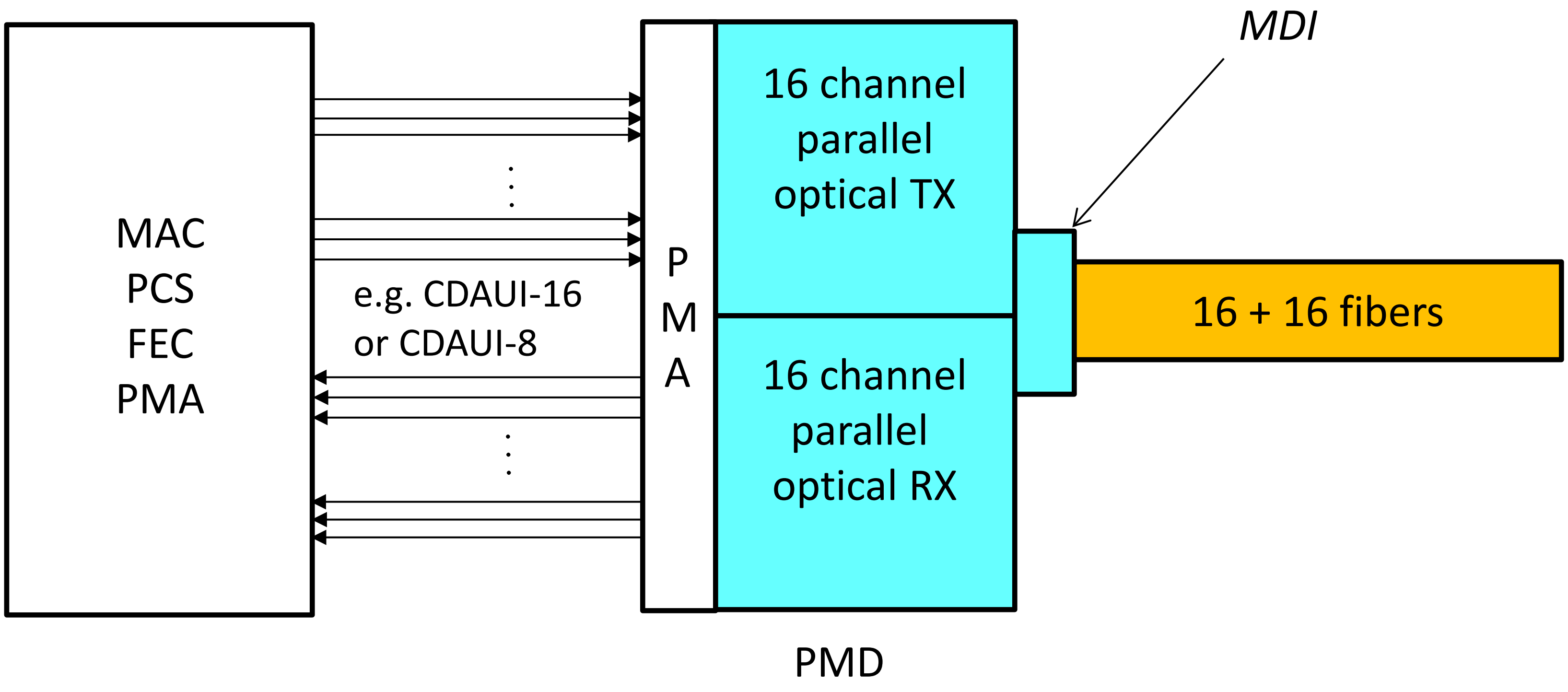
and a very nice letter of support
from the CDFP MSA

Motivation

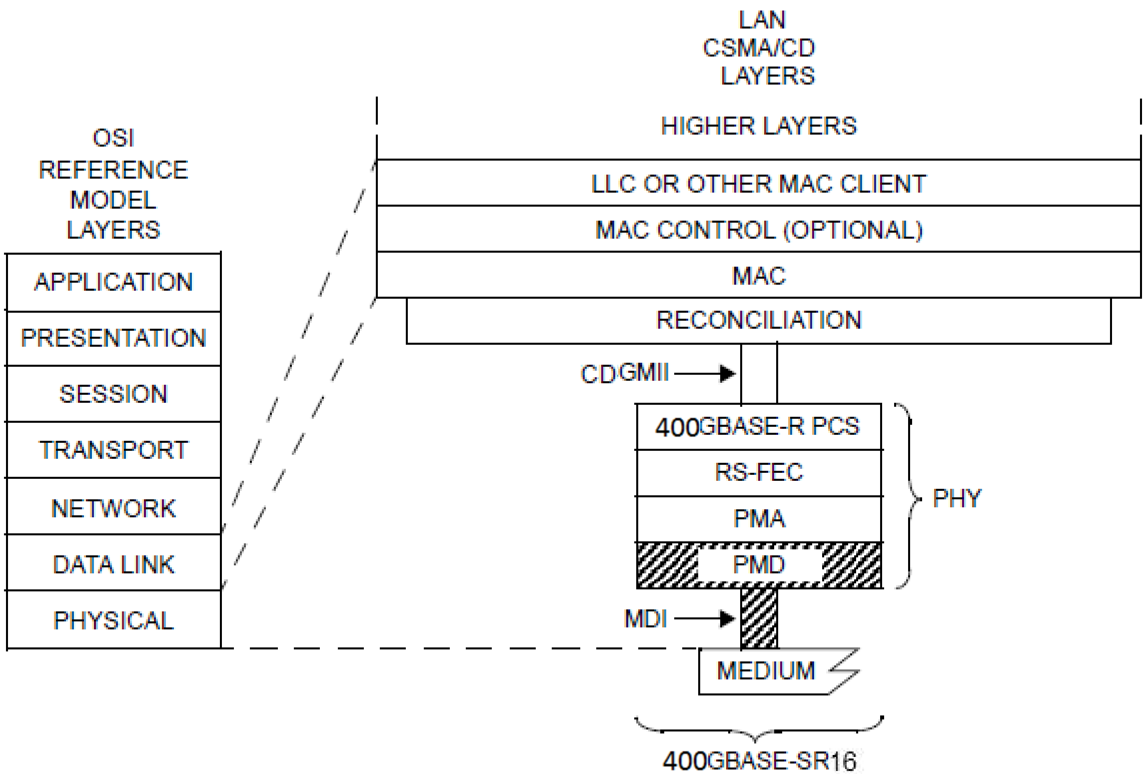
- 16 parallel links operating at 25.78125 GBd utilize low cost, high performing multimode fiber compatible optics and electronics
  - Leverages 100GBASE-SR4 technology
  - FEC supported retimed interface enables a lowest power, lowest cost, 100m solution today
  - Uses existing, viable semiconductor technologies and uncooled VCSELs
- The 16 optical lanes can directly map the 16 electrical lanes of CDAUI-16, without requiring multiplexing, translation, or de-skewing inside the module.
- Compatible with ‘break out’ application
- This proposal is supported by multiple vendors and users, and is economically feasible and competitive compared to other alternatives.

Proposal

- 16 parallel lanes @ 25.78125 GBd for 100GBASE-SR16 over 100 m OM4 fiber.
  - Exact signaling rate is determined by project's choice of FEC.
- 850 nm sources, re-use of 100GBASE-SR4 specifications.
  - Assumes PMD target BER (prior to error correction) around 5×10^{-5}, similar to 100GBASE-SR4.



Position in 802.3 architecture

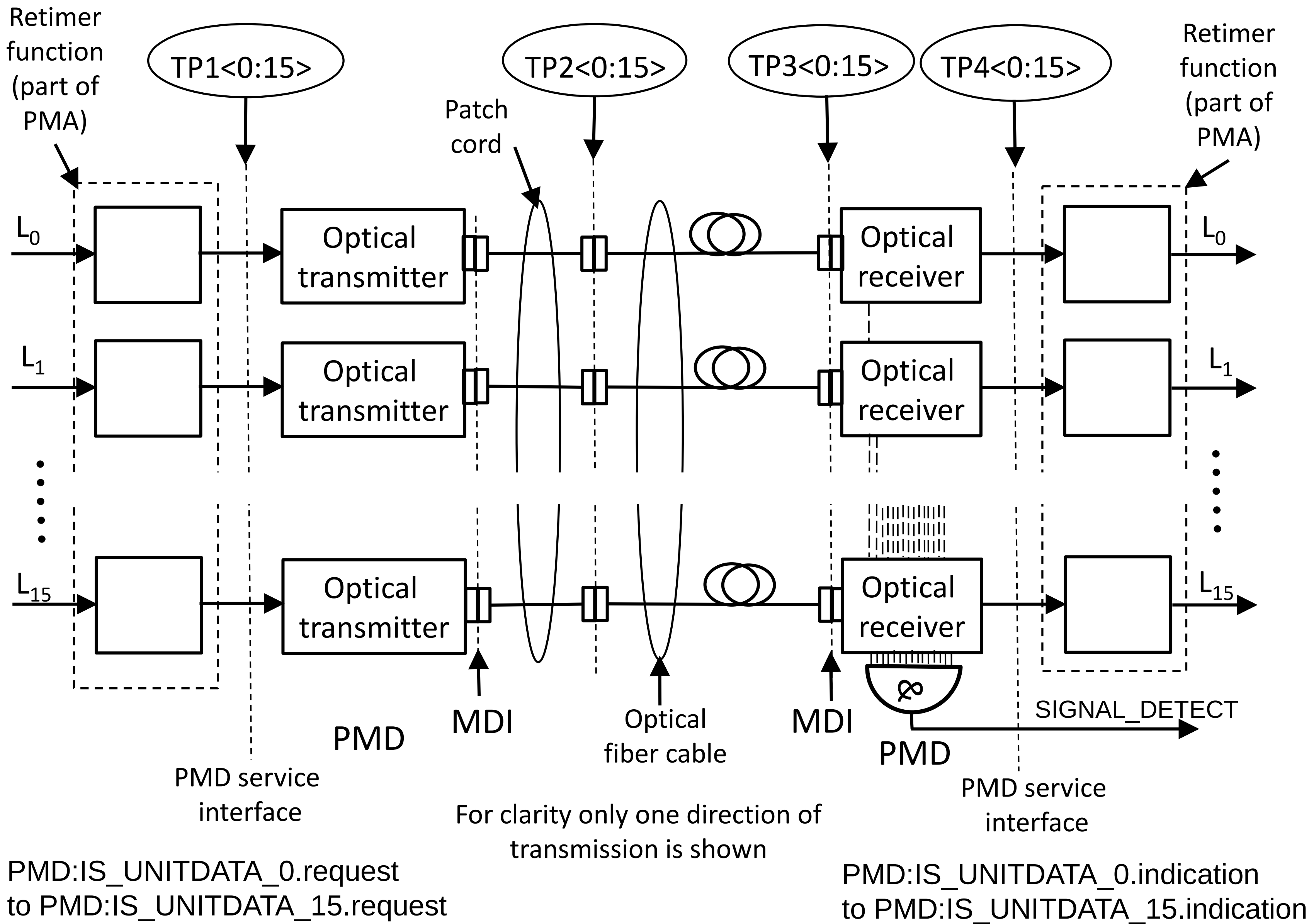


CDGMII = 400 Gb/s MEDIA INDEPENDENT INTERFACE
LLC = LOGICAL LINK CONTROL
MAC = MEDIA ACCESS CONTROL
MDI = MEDIUM DEPENDENT INTERFACE
PCS = PHYSICAL CODING SUBLAYER

PHY = PHYSICAL LAYER DEVICE
PMA = PHYSICAL MEDIUM ATTACHMENT
PMD = PHYSICAL MEDIUM DEPENDENT
RS-FEC = REED-SOLOMON FORWARD ERROR CORRECTION
SR = PMD FOR MULTIMODE FIBER

Editor's note: The RS-FEC layer may be merged into 400GBASE-R PCS layer, depending on the choice of architecture by the Task Force.

Block diagram for 400GBASE-SR16 transmit/receive path



PMD Optical specifications

- Transmitter characteristics (each lane) at TP2 follow 100GBASE-SR4, Clause 95, Table 95-6.
- Receiver characteristics (each lane) at TP3 follow 100GBASE-SR4, Clause 95, Table 95-7.
- Illustrative link power budget follows 100GBASE-SR4, Clause 95, Table 95-8.
  - Current status of these tables shown on next 3 slides

Transmitter characteristics (each lane) at TP2: follow 100GBASE-SR4, Clause 95, Table 95-6 (D3.2 illustrated below)

Description	Value	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm	GBd
Center wavelength (range)	840 to 860	nm
RMS spectral width[a] (max)	0.6	nm
Average launch power, each lane (max)	2.4	dBm
Average launch power, each lane (min)	–9	dBm
Optical Modulation Amplitude (OMA), each lane (max)	3	dBm
Optical Modulation Amplitude (OMA), each lane (min)[b]	–7	dBm
Launch power in OMA minus TDEC (min)	–7.9	dBm
Transmitter and dispersion eye closure (TDEC), each lane (max)	4.9	dB
Average launch power of OFF transmitter, each lane (max)	–30	dBm
Extinction ratio (min)	2	dB
Optical return loss tolerance (max)	12	dB
Encircled flux[c]	≥ 86% at 19 μm ≤ 30% at 4.5 μm	
Transmitter eye mask definition {X1, X2, X3, Y1, Y2, Y3} Hit ratio 1.5×10^{-3} hits per sample	{0.3, 0.38, 0.45, 0.35, 0.41, 0.5}	

[a]RMS spectral width is the standard deviation of the spectrum.
[b]Even if the TDEC < 0.9 dB, the OMA (min) must exceed this value.
[c]If measured into type A1a.2 or type A1a.3 50 μm fiber in accordance with IEC 61280-1-4.

Receiver characteristics (each lane) at TP3: follow 100GBASE-SR4, Clause 95, Table 95-7 (D3.2 illustrated below)

Description	Value	Unit
Signaling rate, each lane (range)	25.78125 ± 100 ppm	GBd
Center wavelength (range)	840 to 860	nm
Damage threshold[a] (min)	3.4	dBm
Average receive power, each lane (max)	2.4	dBm
Average receive power, each lane[b] (min)	–10.9	dBm
Receive power, each lane (OMA) (max)	3	dBm
Receiver reflectance (max)	–12	dB
Stressed receiver sensitivity (OMA), each lane[c] (max)	–5.6	dBm
Conditions of stressed receiver sensitivity test:[d]		
Stressed eye closure (SEC), lane under test	4.9	dB
Stressed eye J2 Jitter, lane under test	0.39	UI
Stressed eye J4 Jitter, lane under test	0.53	UI
OMA of each aggressor lane	3	dBm
Stressed receiver eye mask definition {X1, X2, X3, Y1, Y2, Y3} Hit ratio 5×10^{-5} hits per sample	{0.28, 0.5, 0.5, 0.33, 0.33, 0.4}	

[a]The receiver shall be able to tolerate, without damage, continuous exposure to an optical input signal having this average power level on one lane. The receiver does not have to operate correctly at this input power.
[b]Average receive power, each lane (min) is informative and not the principal indicator of signal strength. A received power below this value cannot be compliant; however, a value above this does not ensure compliance.
[c]Measured with conformance test signal at TP3 (see 95.8.8) for the BER specified in 95.1.1.
[d]These test conditions are for measuring stressed receiver sensitivity. They are not characteristics of the receiver.

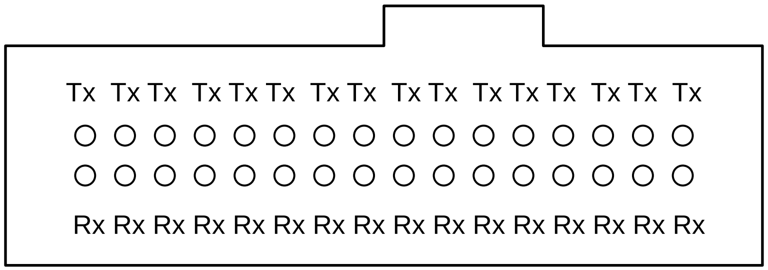
Illustrative link power budget:
follow 100GBASE-SR4, Clause 95, Table 8 (D3.2 illustrated below)

Parameter	OM3	OM4	Unit
Effective modal bandwidth at 850 nm[a]	2000	4700	MHz.km
Power budget (for max TDEC)	8.2		dB
Operating distance	0.5 to 70	0.5 to 100	m
Channel insertion loss[b]	1.8	1.9	dB
Allocation for penalties[c] (for max TDEC)	6.3		dB
Additional insertion loss allowed	0.1	0	dB

[a]per IEC 60793-2-10.
[b]The channel insertion loss is calculated using the maximum distance specified in Table 95–5 and cabled optical fiber attenuation of 3.5 dB/km at 850 nm plus an allocation for connection and splice loss given in 95.11.2.1.
[c]Link penalties are used for link budget calculations. They are not requirements and are not meant to be tested.

Medium Dependent Interface (MDI) for 400GBASE-SR16 and lane assignments

- Similar to the MDI defined for 100GBASE-SR10 (Clause 86.10.3.3, Recommended Option A), but using MPO-16, a 16-wide version of the 100G-SR10 MDI.
- Transmitters occupy the top row and receivers occupy the bottom row for better heat dissipation



400GBASE-SR16 optical lane assignments for the MDI receptacle when viewed looking into the receptacle with keyway feature on top.

  - The following 4 slides show draft text and figures which describe the MDI and lane assignments, using clause 86 and 95 content as basis, with modifications for 400GBASE-SR16 and MPO-16

MDI (1 of 4)

xx.m.n Medium Dependent Interface (MDI)

The 400GBASE-SR16 PMD is coupled to the fiber optic cabling at the MDI. The MDI is the interface between the PMD and the "fiber optic cabling" (as shown in Figure xx-a). The 400GBASE-SR16 PMD is coupled to the fiber optic cabling through one connector plug into the MDI optical receptacle as shown in Figure xx-b. Example constructions of the MDI include the following:

a) PMD with a connectorized fiber pigtail plugged into an adapter;
b) PMD with receptacle.

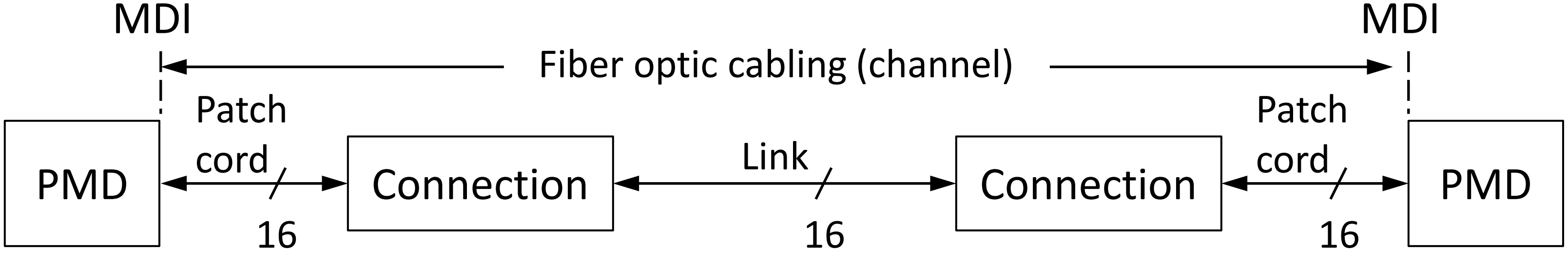


Figure xx-a – Fiber optic cabling model

Editor's note: Figure xx-a may be placed in a preceding subclause

MDI (2 of 4)

xx.m.n.1 Optical lane assignments

The sixteen transmit and sixteen receive optical lanes of 400GBASE-SR16 shall occupy the positions depicted in Figure xx-b viewed looking into the MDI receptacle with the connector keyway feature on top. The interface contains 32 active lanes within 32 total positions. The transmit optical lanes occupy the top row. The receive optical lanes occupy the bottom row. See clause xx.m.n.2 for MDI optical connector requirements.

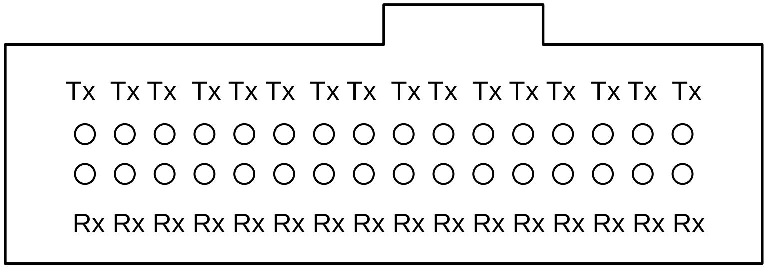


Figure xx-b -- 400GBASE-SR16 optical lane assignments viewed looking into the MDI receptacle with keyway feature on top.

MDI (3 of 4)

xx.m.n.2 Medium Dependent Interface (MDI) requirements

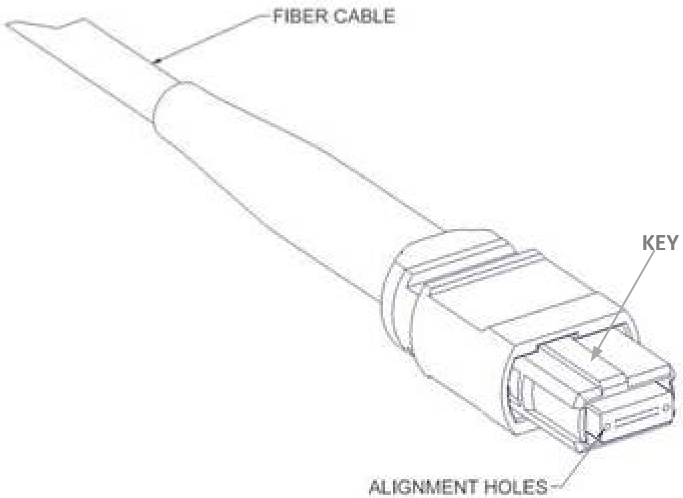
The MDI adapter or receptacle shall meet the dimensional specifications of ANSI/TIA-604-18 adapter designation FOCIS 18A-k-0. The plug terminating the optical fiber cabling shall meet the dimensional specifications of ANSI/TIA-604-18 female plug connector flat interface designation FOCIS 18P-2x16-1-0-2-2. The MDI shall optically mate with the plug on the optical fiber cabling. Figure xx-c shows an MPO-16 female plug connector with flat interface, and an MDI.

The MDI connection shall meet the interface performance specifications of IEC 61753-1 and IEC 61753-022-2.

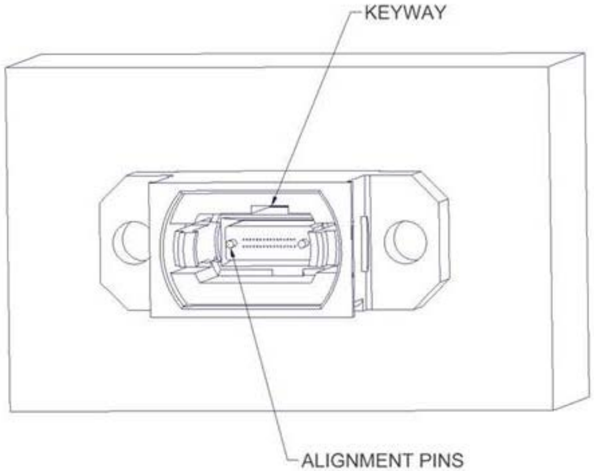
NOTE— Transmitter compliance testing is performed at TP2 as defined in xx.k.j, not at the MDI.

Editor's note: ANSI/TIA-604-18 presently entering third ballot.
IEC has not yet initiated ballot on the equivalent connector.

MDI (4 of 4)



MPO-16 female plug connector flat interface



MDI

Figure xx-c – MPO-16 female plug connector flat interface and MDI

Editor’s note: Figure is in public domain so may be used “as is”. It is also acceptable redrawn in a form like Figure 86-8 with keying adjustment.

Further work

- The PMD target BER is likely to deviate from 5×10^{-5}, so some fine tuning of parameters may be required.
  - The project's choice of FEC will determine the pre-FEC BER target, and may also affect the exact signaling rate.
- Confirm skew budget