International Photonics & Electronics Committee

400G-eSR8 Implementation Agreement

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400G-eSR8 Implementation Agreement

Version 1.0

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400G-eSR8 Implementation Agreement

▪ Summary

The objective of this document is to define one 400 Gb/s PMD for operation over multi-mode fibers (MMF) with lengths up to at least 200 m.

▪ Keywords

400G, eSR, PAM4

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TITLE: 400G-eSR8 Implementation Agreement

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▪ Revision History

Rev	Date	Description
D0.1	2024-11-19	Initial release of this IA.
D0.2	2025-03-17	Some editorial modifications.
D0.9	2025-04-23	Add description about optical interfaces, and some editorial modifications.
D1.0	2025-06-10	Draft Version 1.0
D1.1	2025-07-16	Draft Version 1.1
V1.0	2025-08-23	Released after IPEC's BoD approval.

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1 Introduction

This Implementation Agreement (IA) specifies physical layer specifications and parameters for 400 Gb/s optical interfaces.

The objective of this document is to define a 400 Gb/s Physical Medium Dependent (PMD) sublayer for operation over multi-mode fibers (MMF) with lengths up to at least 200 m.

1.1 Scope

This IA defines an optical interface for 400 Gb/s optical transceivers in Ethernet applications. Forward error correction (FEC) is required to be implemented by the host to ensure reliable system operation. The transceiver communicates over MMF of lengths from 2 meters up to at least 200 meters. The transceiver's electrical interface is not specified by this IA but can have, for example, eight lanes in each direction, with a nominal signaling rate of 53.125 Gb/s per lane.

A variety of form factors for the transceivers are possible and none are precluded by this IA.

1.2 Hardware Signaling Pins

Hardware signaling pins are specified in the multi-source agreements (MSAs) of respective module form factors.

1.3 Module Management Interface

The contents of the various ID registers shall comply with the requirements of the module MSAs.

1.4 High-Speed Electrical Characteristics

The detailed high-speed electrical characteristics are not defined by this IA. 400GE modules should be implemented in compliance with applicable electrical interface specifications.

1.5 FEC Requirements

400GE links rely on the host system implementing the 400GBASE-R PCS layer in accordance with clauses from the IEEE Std 802.3-2022™ and IEEE Std 802.3ck-2022™.

1.6 Mechanical Dimensions

Mechanical dimensions are defined in the MSA specifications of module form factors. This IA does not specify the use of a specific form factor.

Figure 1 shows the block diagram of a 400G eSR8 module with eight optical transmitters and eight optical receivers.

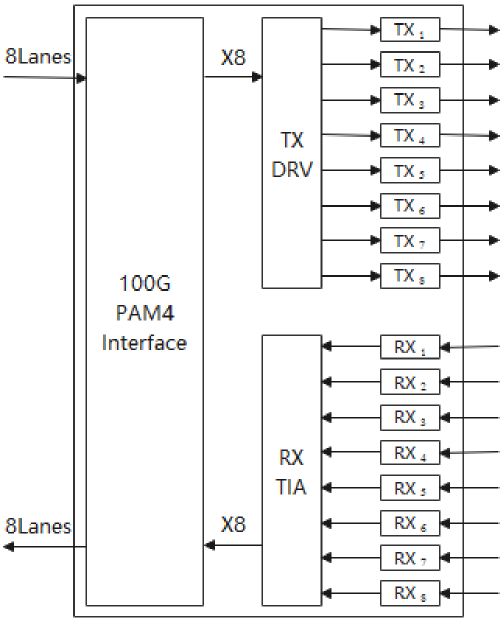

Figure 1 400G-eSR8 module block diagram

2 400G-eSR8 Optical Specifications

This IA defines the 400G-eSR8 optical interface for 400 Gb/s optical transceivers. The following tables show the common parameters: operating range, optical transmit characteristics, 400G-eSR8 optical receive characteristics and optical link budget.

Table 1 400G-eSR8 operating range

PMD Type	Required Operating Range
400G-eSR8	2 m–200 m for OM4

Table 2 400G-eSR8 optical transmit characteristics

Description	Value	Unit
Signaling rate (range)	26.5625±100 ppm	GBd
Modulation format	PAM4	-
Wavelength (range)	840 to 860	nm
RMS spectral width	0.55	nm
Average launch power, each lane (max)	4	dBm
Average launch power, each lane (min)	-6.5	dBm
Outer optical modulation amplitude (OAMouter) (max)	3	dBm
Outer optical modulation amplitude (OMAouter) (min) for TDECQ < 1.4 dB	-3.5 -4.9+TDECQ	dBm

for 1.4 dB ≤ TDECQ ≤ 3.9 dB		
Transmitter and dispersion eye closure for PAM4 (TDECQ) (max)	3.9	dB
TDECQ-10log10(Ceq), each lane (max)	3.9	dB
Average launch power of OFF transmitter (max)	-30	dBm
Extinction ratio (min)	3.0	dB
Transmitter transition time (max)	34	ps
$RIN_{12}OMA$ (max)	-128	dB/Hz
Optical return loss tolerance (max)	12	dB
Encircled flux, each lane	≥ 86% @ 19 µm ≤ 30% @ 4.5 µm	

Table 3 400G-eSR8 optical receive characteristics

Description	Value	Unit
Signaling rate (range)	26.5625±100 ppm	GBd
Modulation format	PAM4	-
Wavelengths (range)	840 to 860	nm
Damage threshold, each lane	5	dBm
Average receive power, each lane(max)	4	dBm
Average receive power, each lane (min)	-8.4	dBm
Receive power (OMAouter), each lane (max)	3	dBm
Receiver reflectance (max)	-12	dB
Receiver sensitivity (OMAouter) (max)	RS = max (-6.5, SECQ – 7.9)	dBm
Stressed receiver sensitivity (OMAouter) (max)	-3.4	dBm
Conditions of stressed receiver sensitivity test:		
Stressed eye closure for PAM4 (SECQ)	4.5	dB
SECQ – 10log10(Ceq)f (max), lane under test	4.5	dB
OMAouter of each aggressor lane	3	dBm

Table 4 400G-eSR8 optical link budget

Description	Value	Unit
Effective modal bandwidth at 850 nm[a]	4700	MHz.km

Power budget (for max TDECQ):	6.9	dB
Operating distance	200	m
Channel insertion loss[b]	2.4	dB
Maximum discrete reflectance	-35	dB
Allocation for penalties (for max TDECQ):	3.9	dB
Additional insertion loss allowed	0.6	dB

[a] Per IEC 60793-2-10.

[b] The channel insertion loss is calculated using the maximum distance specified in Table 1 with a cabled optical fiber attenuation of 3.5 dB/km at 850 nm plus a 1.7 dB allocation for total connection and splice loss.

2.1 400G-eSR8 Illustrative Link Power Budget

Figure 2 shows 400G-eSR8 optical link budget and sensitivity mask.

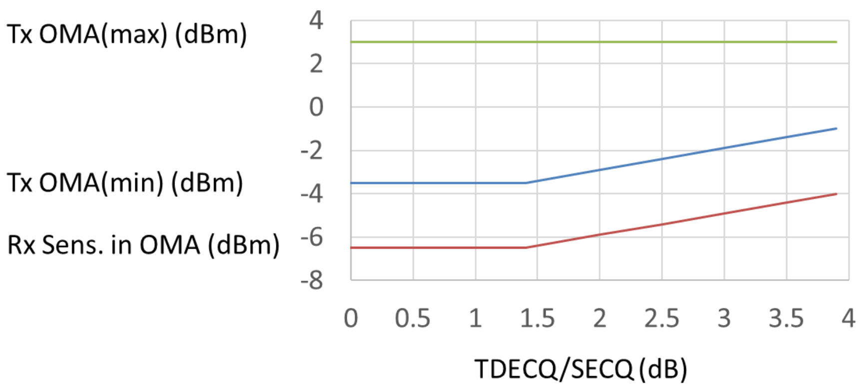

Figure 2 400G-eSR8 optical link budget and sensitivity mask

3 Definition of Optical Parameters and Measurement Methods

The specific test patterns are defined in Table 138-11 of IEEE Std 802.3-2022 [1].

3.1 Test Patterns for Optical Parameters

Detailed information on the test patterns for optical parameters is available in Clause 138.8 of IEEE Std 802.3-2022 [2].

3.2 Skew and Skew Variation

The skew and skew variation are available in Clause 138.3 of IEEE Std 802.3-2022 [1].

3.3 Wavelength and Spectral Width

The center wavelength and RMS spectral width of each optical lane shall be within the range given in Table 3 if measured per IEC 61280-1-3. The lane under test should be modulated using test patterns specified in Clause 3.1.

3.4 Average Optical Power

The specific average optical power shall be within the limit given in Table 2 if measured per IEC 61280-1-1 and using one of the test patterns specified in Clause 3.1.

3.5 Optical Modulation Amplitude (OMAouter)

The specific definition of OMAouter is defined in Clause 121.8.4 of IEEE Std 802.3-2022 [1].

3.6 Transmitter and Dispersion Eye Closure for PAM4 (TDECQ)

The methodology of TDECQ is specified in Clause 167.8.6 of IEEE Std 802.3db-2022 [2].

3.6.1 TDECQ Reference Equalizer

The TDECQ reference equalizer is defined in Clause 167.8.7 of IEEE Std 802.3db-2022 [2].

3.7 Extinction Ratio

The test method of extinction ratio is defined in Clause 121.8.6 of IEEE Std 802.3-2022 [1]. The extinction ratio of each lane shall be compliant to the limit listed in Table 2.

3.8 Transmitter Transition Time

The test method of transmitter transition time is defined in Clause 138.8.7 of IEEE Std 802.3-2022 [1]. The transmitter transition time of each lane shall be compliant to the limit listed in Table 2.

3.9 Relative Intensity Noise ($RIN_{12}OMA$)

The test method of $RIN_{12}OMA$ is defined in Clause 138.8.8 of IEEE Std 802.3-2022 [1]. RIN12OMA of each lane shall be compliant to the limit listed in Table 2.

3.10 Receiver Sensitivity

The test method of $RIN_{12}OMA$ is defined in Clause 138.8.8 of IEEE Std 802.3-2022 [1]. $RIN_{12}OMA$ of each lane shall be compliant to the limit listed in Table 2.

3.11 Stressed Receiver Sensitivity

The test method of stressed receiver sensitivity is defined in Clause 138.8.10 of IEEE Std 802.3-2022 [1].

4 Fiber Optic Cabling Model

The fiber optic cabling model of 400G-eSR8 is shown in **Figure 3**.

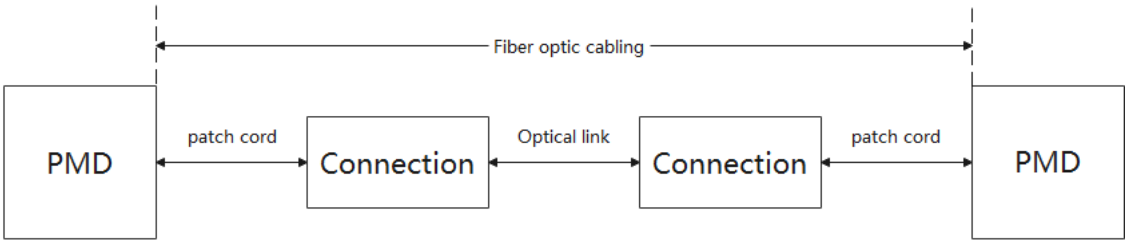

Figure 3 Fiber optic cabling model

5 Characteristics of the Fiber Optic Cabling (Channel)

The channel insertion loss is calculated using the maximum distance specified in Table 1 with a cabled optical fiber attenuation of 3.5 dB/km at 850 nm plus a 1.7 dB allocation for total connection and splice loss. The fiber optic cabling requirements for 400G-eSR8 are specified in Table 5

Table 5 Fiber optic cabling characteristics (channel) for 400G-eSR8

Description	400G-ESR8	Unit
Operating distance (max)	200	m
Channel insertion loss[a] (max)	2.4	dB
Cabling skew (max)	79	ns
Cabling skew variation	4.8	ns
Discrete reflectance (max)	-20	dB
Additional loss allowed	0.6	dB

[a] The channel insertion loss includes connectors, splices, and more, and is over the wavelength range as specified in Table 2.

6 Optical Interfaces

This specification defines two mandatory Media Dependent Interfaces (MDIs). The spatial alignment of transmit (Tx) and receive (Rx) optical lanes shall comply with the geometric configurations defined in Figure 4, Figure 5 when viewed with the connector keying feature oriented in the upward position.

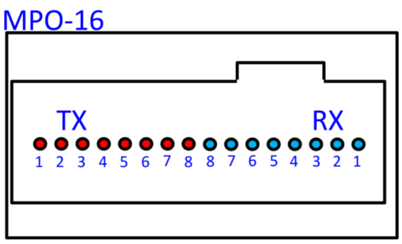

Figure 4 MPO-16 MDI

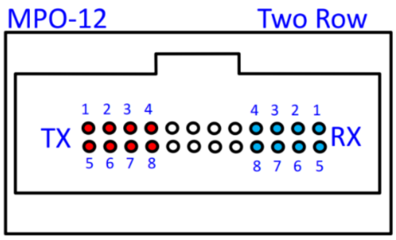

Figure 5 MPO-12 Two Row MDI

MPO (Multi-fiber Push-On) connectors shall utilize rectangular ferrules to align and secure optical fibers in standardized arrays (e.g., 12, 16, or 24 fibers see Figure 7&8&9). Connector keying and polarization shall comply with IEC 61754-7 and TIA-604-5 specifications, ensuring consistent Tx/Rx channel assignment per predefined fiber sequences.

Figure 6 MPO-16 One row optical connector and module receptacle

Figure 7 MPO-12 Two rows optical connector and module receptacle

7 References

7.1 Normative References

1. IEEE Std 802.3-2022: IEEE Standard for Ethernet
2. IEEE Std 802.3db-2022: IEEE Standard for Ethernet Amendment 3: Physical Layer Specifications and Management Parameters for 100 Gb/s, 200 Gb/s, and 400 Gb/s Operation over Optical Fiber Using 100 Gb/s Signaling
3. IEEE Std 802.3ck-2022™ IEEE Standard for Ethernet Amendment 4: Physical Layer Specifications and Management Parameters for 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Based on 100 Gb/s Signaling

8 Appendix A: Abbreviations and Acronyms

The following abbreviations and acronyms are used in this IA:

DeMUX	Demultiplexer
DGD	Differential Group Delay
DRV	Driver
FEC	Forward Error Correction
IA	Implementation Agreement
MSA	Multisource Agreement
MUX	Multiplexer
OMA	Optical Modulation Amplitude
OMAouter	Outer Optical Modulation Amplitude
PCS	Physical Coding Sublayer
PMA	Physical Medium Attachment
PMD	Physical Medium Dependent
PRBS	Pseudo-Random Bit Sequence
QSFP	Quad Small Form Factor Pluggable
RIN	Relative Intensity Noise
RX	Receiver
SECQ	Stressed Eye Closure for PAM4
SMF	Single Mode Fiber
SMSR	Side-Mode Suppression Ratio
SSPRQ	Short Stress Pattern Random Quaternary
TDECQ	Transmitter and Dispersion Eye Closure for PAM4
TIA	Transimpedance Amplifier
TX	Transmitter

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