



OPEN

Compute Project

Optical Transceiver

400G QSFP112 SR4

OCP Immersion Active Optical Pigtail (iAOP)

Specification V0.1

Product Specification

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Author: Eric Chen, FormericaOE

Compliance with OCP Tenants

Openness

By migrating the Immersion Active Optical Cable & Pigtail Specifications to the Open Compute foundation, they become open to all to review and implement. In addition, the broad membership of the OCP is able to contribute to the future development of the specification.

Efficiency

The purpose of the Immersion Active Optical Cable Specification is to drive commonality in implementations of iAOCs/iAOPs in order to reduce friction in adoption users. This directly reduces opex in the form of qualifications and firmware work to adapt to different iAOC/iAOP implementations.

Impact

Immersion Active Optical Cables or Pigtails have proven to be essential components of hyperscale and service provider networks in order to enable high speed, low cost, low power and highly reliable networks. Migrating this specification to OCP drives commonality in these implementations and a broader membership base to widen impact.

Scale

Multiple hyperscalers have deployed or are planning to deploy Active Optical Cables. Soon they shall be deployed in immersion cooling.

Similarly to optical connectors in Air/DLC, the CMIS/DDMI monitoring functions ensure the Data Center Fabric is performing at its optimal.

Sustainability

Active Optical Cables & Pigtails ease fabric connection complexity. Immersion Active Optical Cables & Pigtails allows the fabric to function in immersion cooling, which lowers PUE of data centers for AI/ML/HPC.

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Scope and Overview

1.1 Scope

This document defines the technical specifications for the 400G QSFP112 SR4 OCP Immersion Active Optical Pigtail (iAOP) used in large-scale data center applications.

1.2 Overview

The 400G QSFP112 SR4 iAOP OCP optical specification is based on 400GBASE-SR4 as defined in IEEE 802.3 db and IEEE 802.3 ck.

This optimization involves the adoption of coolant-compatible materials, preservation of optical path integrity, and validated thermal performance to ensure reliable operation in immersion liquid-cooling environments. Considering the characteristics of liquid cooling fluid and the operation mode of the cooling system, temperature specifications of the product have been relaxed. The temperature range shall be relaxed from 0-70°C to RT-70°C. (Note, the RT value depends on dew point of the air).

While this specification is focused on 400G operation, the module shall be compliant to the IEEE 802.3 db and IEEE 802.3 ck.

2 Common Terms

The following terms are used in this document

2.1 Parameter related

AOP - Average Optical Power
OMA - Optical Modulation Amplitude
TDECQ - Transmitter Dispersion Eye Closure Quaternary
ER - Extinction Ratio
SMSR - Side Mode Suppression Ratio
BER - Bit Error Rate
FEC - Forward Error Correction
PAM4 - 4-level Pulse Amplitude Modulation
Gbps - Gigabit per second
GBd - Gigabaud

2.2 Product related

iAOP - Immersion Active Optical Pigtail
iAOC - Immersion Active Optical Cable
AOC - Active Optical Cable
CT - Commercial Temperature
IT - Industrial Temperature
LPMode - Low Power Mode
I2C - Inter-Integrated Circuit
SR - Short reach
LR - Long reach

2.3 Fiber

MMF - Multi-Mode Fiber

SMF - Single-Mode Fiber

OM3 - Optical Multimode 3

PC - Physical Contact

APC - Angled Physical Contact

MPO - Multiple-Fiber Push-On

2.4 Standard

CWDM - Coarse Wavelength Division Multiplex

IEEE - Institute for Electrical and Electronics Engineers

MSA - Multi-Source Agreement

SFF - Small Form Factor

QSFP - Quad Small Form Factor Pluggable

QSFP112 - Quad Small Form Factor Pluggable Module 112

QSFP-DD - QSFP–Double Density

OSFP - Octal Small Form Factor Pluggable Module

OSFP-RHS - OSFP-Riding Heat Sink

CMIS - Common Management Interface Specification

3 Operating Conditions

Recommended Operating Conditions		
Parameters	Value	Unit
Case Operating Temperature	RT ~ 70 Note1	°C
Power Supply Voltage (Typical)	3.3	V
Power Consumption (Max)	9	W
Data Rate per Channel (Typical)	53.125	GBd

Note1: RT (Room Temp) value depends on dew point of the air

4 Specifications

4.1 Electrical Transmitter Characteristic

Electrical Transmitter Characteristics		
Parameters	Value	Unit
Differential pk-pk Input Voltage tolerance(min)	750	mV
Differential Termination Mismatch (max)	10	%
Eye height(min)	10	mV
Common-mode to differential-mode return loss	IEEE802.3 ck Equation (120G-1)	dB
Vertical eye closure(max)	12	dB
Effective return loss(min)	7.3	dB
Transition Time(min)	10	ps

4.2 Electrical Receiver Characteristic

Electrical Receiver Characteristics		
Parameters	Value	Unit
Pre FEC Bit Error Ratio	2.4E-4	
Post FEC Bit Error Ratio	1E-12	
Differential data output swing	300~900	mVpp
Differential termination mismatch (max)	10	%
Eye height (min)	15	mV
Vertical eye closure (max)	12	dB
Common-mode to differential-mode return loss	IEEE802.3 ck Equation (120G-1)	
Effective return loss	8.5	dB
Transition time	8.5	ps

4.3 Optical Transmitter Characteristic

Optical Transmitter Characteristics			
Parameter		Value	Unit
Data rate per lane		53.125	GBd
Modulation format		PAM4	
Center Wavelength		844 ~ 863	nm
RMS spectral width (max)		0.6	nm
Average Launch power, each lane		-4.6~4.0	dBm
Optical Power OMA, each Lane, (max)		3.5	dBm
OMA _{outer} , each lane min	max (TECQ, TDECQ) <1.8 dB	max [-2.6 , max(TECQ,TECQ) – 4.4]	dBm
	1.8 < max (TECQ, TDECQ) < 4.4 dB		
Transmitter and dispersion eye closure (TDECQ), each lane (max)		4.4	dB
Transmitter eye closure for PAM4 (TECQ), each lane(max)		4.4	dB
Extinction ratio (min)		2.5	dB
Transmitter power excursion, each lane (max)		2.3	dBm
Optical Return Loss Tolerance (max)		14	dB
Optical Power for TX DISABLE (max)		-30	dBm
Encircled flux _b ²		≥86% at 19 um ≤30% at 4.5 um	

Notes:

1. Defined according to the performance of the laser used.
2. Measured into type A1a.2 or type A1a.3, or A1a.4, 50 um fiber, in accordance with IEC 61280-1-4.

4.4 Optical Receiver Characteristics

Optical Receiver Characteristics			
Parameter		Value	Unit
Data rate per lane		53.125	GBd
Modulation format		PAM4	
Center Wavelength		844~863	nm
Damage threshold(min)		5	dBm
Average receive power, each lane(min)		-6.4~4	dBm
Receive power, each lane (max)(OMAouter)(max)		3.5	dBm
Receiver reflectance(max)		-15	dB
Receiver sensitivity, each lane ¹		RS = max (-4.6 , TECQ – 6.4)	dBm
Stressed receiver sensitivity, each lane (max)		-2.0	dBm
Rx LOS	Assert	-15	dBm
	De-assert(max)	-7.5	dBm
	Hysteresis	0.5~5	dB

Notes:

1. Receiver sensitivity is informative and is defined for a transmitter with a value of TECQ. Measured with conformance test signal at TP3 for BER = 2.4E-4 Pre-FEC.

4.5 Optical Fiber Link Model

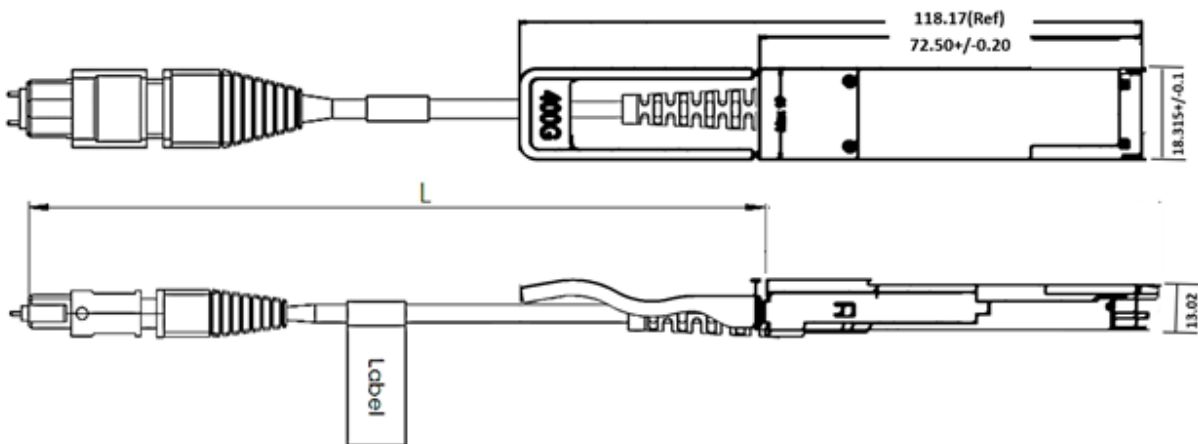
The reference optical fiber link model is based on MMF fiber. The distance. Refer to IEEE 802.3 db and IEEE 802.3 ck.

Optical Fiber Link Model	
400GBase-SR4	0.5m to 60m for OM3
	0.5m to 100m for OM4

5 Form Factor

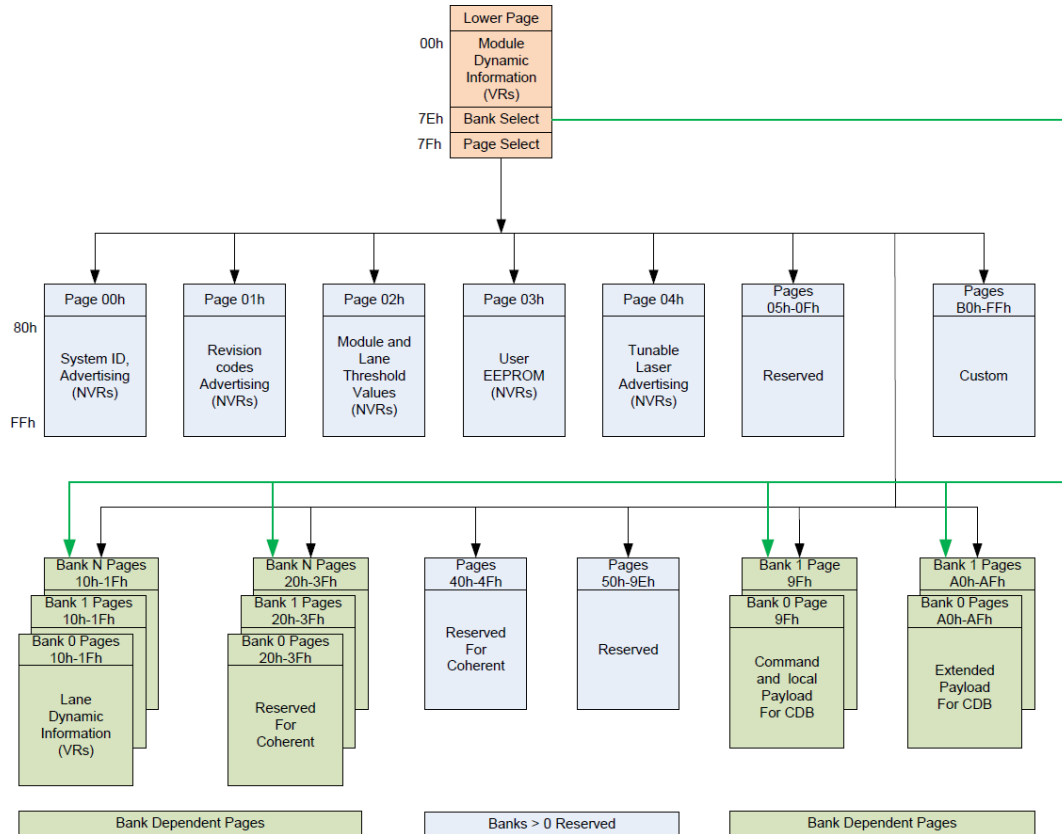
The QSFP112 form factor described in QSFP112 MSA shall be used.

5.1 Mechanical Drawing



6 Management Interface

The module is compliant to CMIS.



7 Immersion Cooling Requirements

Immersion products must be materially compatible with the immersion fluid and perform equal or better in the immersion fluid.

This involves utilizing the testing conditions specified in the OCP “Material Compatibility in Immersion Cooling” guideline (80°C, 0.8L, 336 hours) and adhering to the acceptance criteria to determine if the material is compatible (< 10% change in weight, length, diameter, etc. before and after test).

Only compatible materials should be used in immersion products.

8 Reference

The following documents are referenced in this specification:

- IEEE 802.3 db, IEEE 802.3 ck.
- CMIS
- QSFP112 MSA
- OCP Material Compatibility in Immersion Cooling Rev 1.0
- OCP Immersion Requirements Rev 2.1

9 Revisions

Rev	Date	Description
0.1	July 15 th , 2025	Initial Release