Co-Packaging Interoperability Demo ECOC 2023

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Co-Packaging Interoperability Demonstration

- Co-Packaging Framework Document
- 3.2T Optical Module for Co-Packaging Project
- ELSFP Project
- Electrical Interfaces for Co-Packaging
- Interoperability Demonstrations

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What is a Framework Document?

Framework Project

- A framework project has been a successful vehicle for the OIF.
- It enables the OIF membership to explore next generation industry needs and to forge an industry consensus, particularly with respect to interoperable solutions by:
  - Identifying the various application needs (application spaces)
  - Identifying points where interoperability is important
  - Identifying what kinds of parameters should be interoperable
  - Identifying additional projects which can nail down specifics for interoperability
- It results in a framework document detailing how the OIF can address next generation industry needs through follow on implementation agreements.

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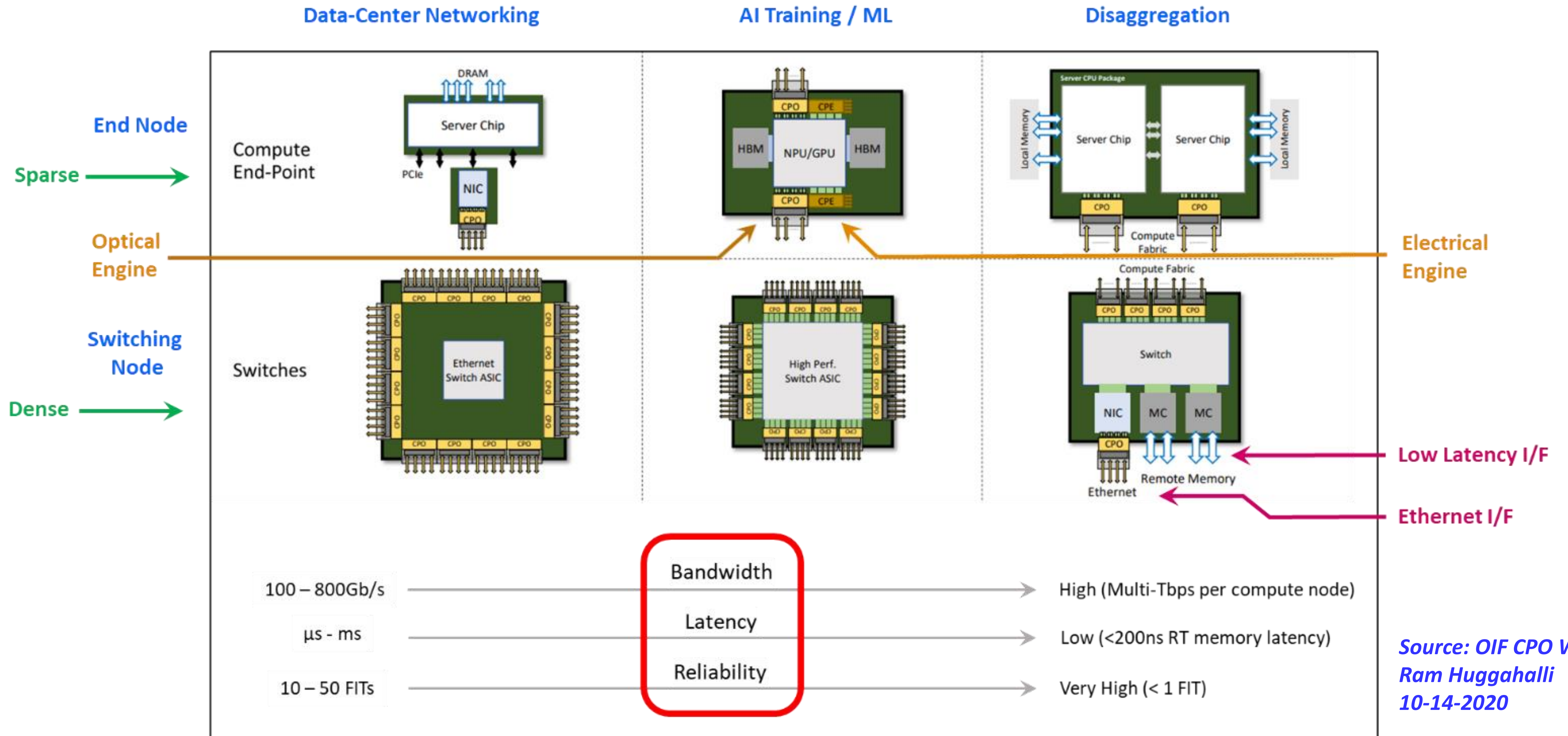
Co-Packaging Application Spaces

Framework Project



Source: OIF CPO Webinar, Ram Huggahalli 10-14-2020

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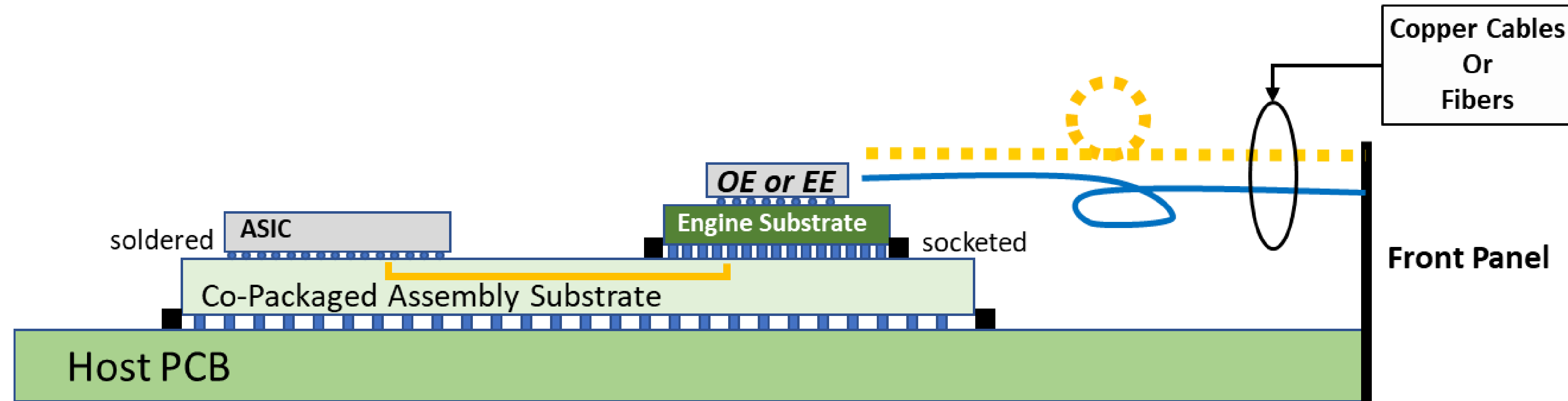
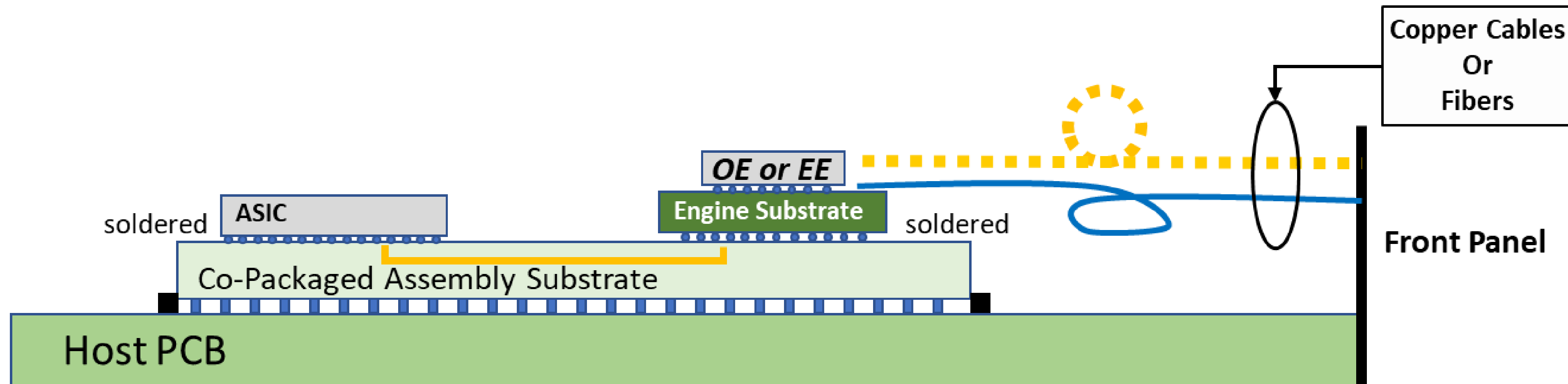
Co-Packaging Architectures (1)

Framework Project

Co-Packaged using socket for engine



Co-Packaged with soldered engine



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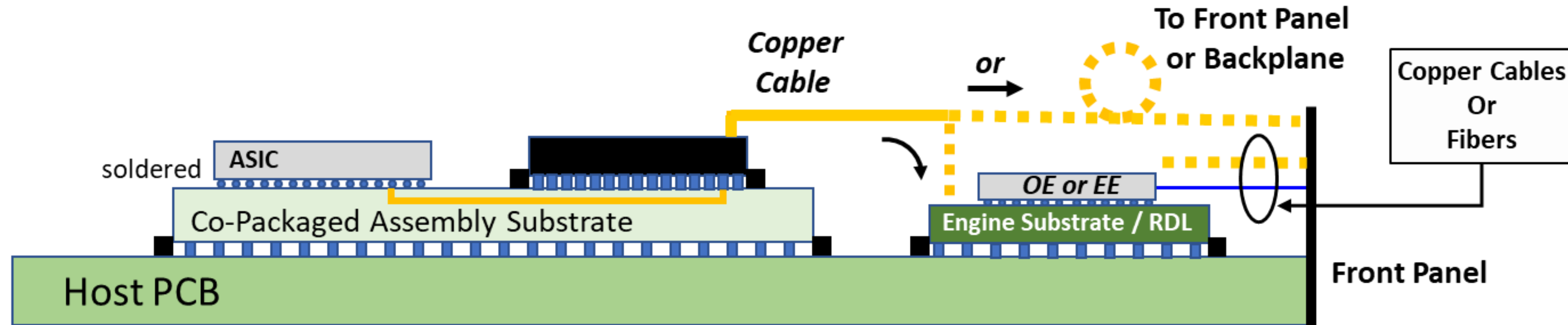
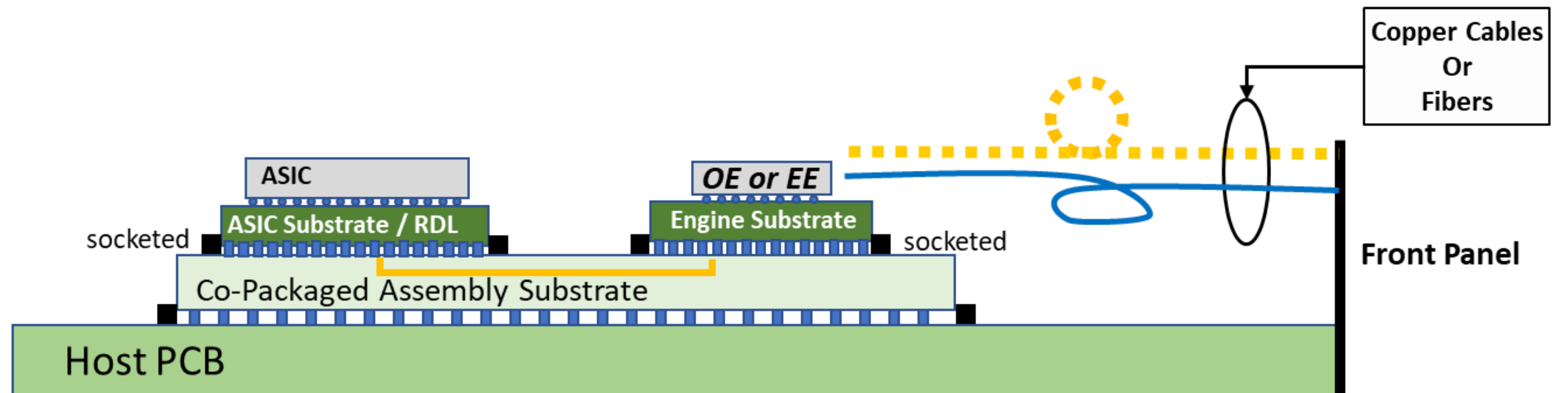
Co-Packaging Architectures (2)

Framework Project

Co-Packaged using copper cable assembly



Near-Packaged using socketed engine



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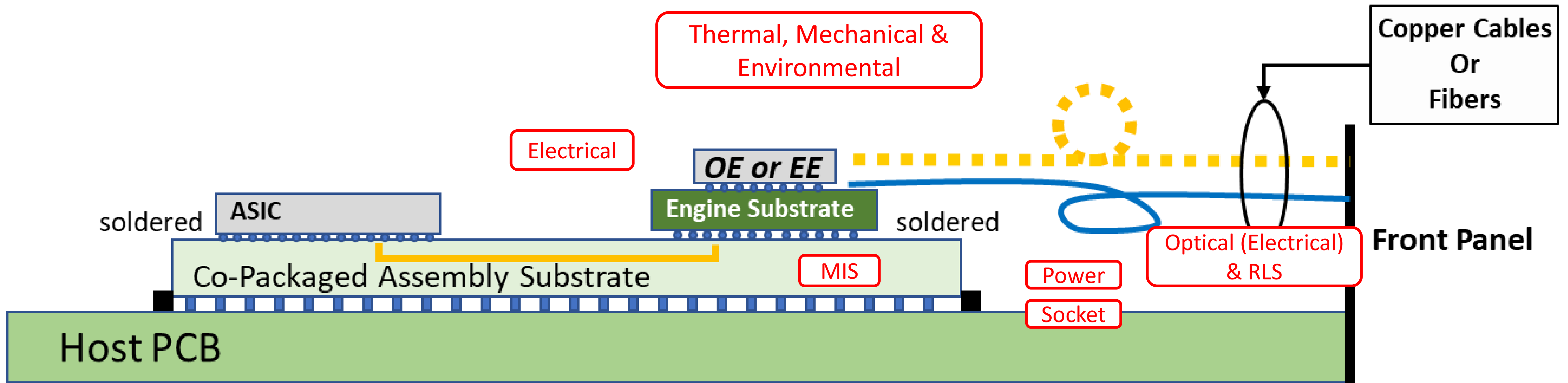
Interfaces Studied for Interoperability

Framework Project



Application Example

- **Switch Generation:** 51.2Tb/s
- **Lane Speed:** 106 Gb/s
- **Interface Architecture:** XSR based AUI, 400G-FR4 PMD
- **Motivation:** System power reduction, ecosystem & operational readiness

Reliability and Repairability

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Overview
3.2T Optical Module

- The OIF started the 3.2T Module Project Feb 2021
  - Project proposed by Facebook (now Meta), Microsoft, Ranovus, Intel, with a large industry backing
- The initial goal was to create:
  - A 3.2T Optical Co-Packaged Module IA for 51T data-center switch applications
- This presentation aims to update the industry on our progress so far…
- Contributions and collaboration from many members are included in here, with sincere appreciation from the Editor

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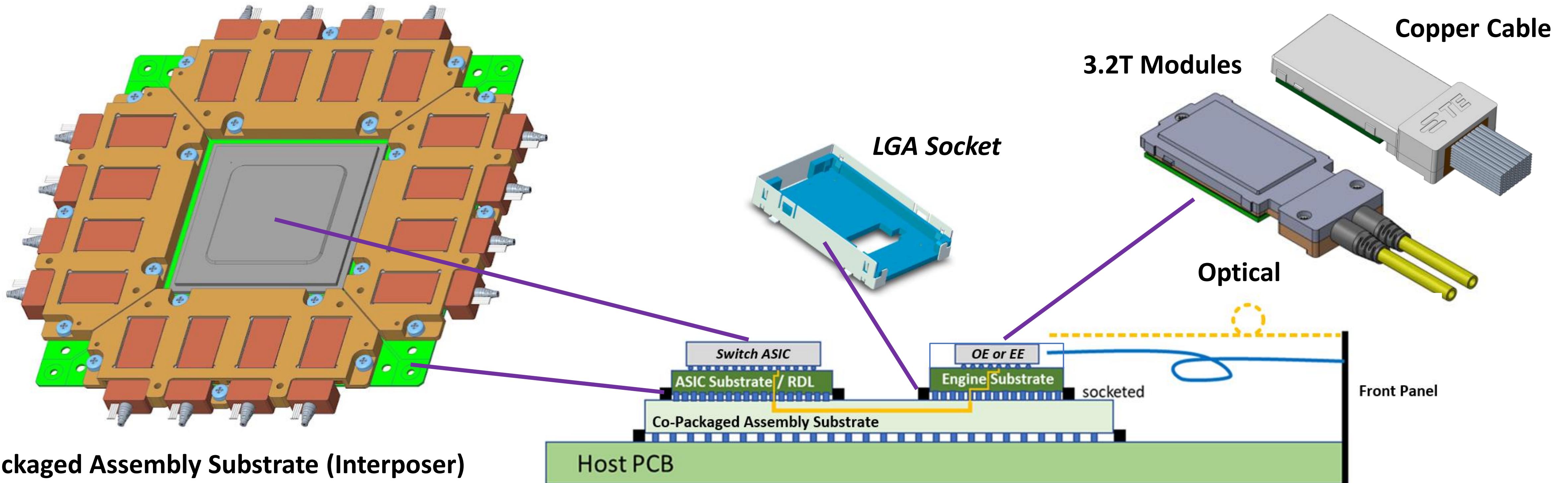
Example System Attachment

3.2T Optical Module

- 16 x 3.2T Modules = 51.2T Switch Capacity



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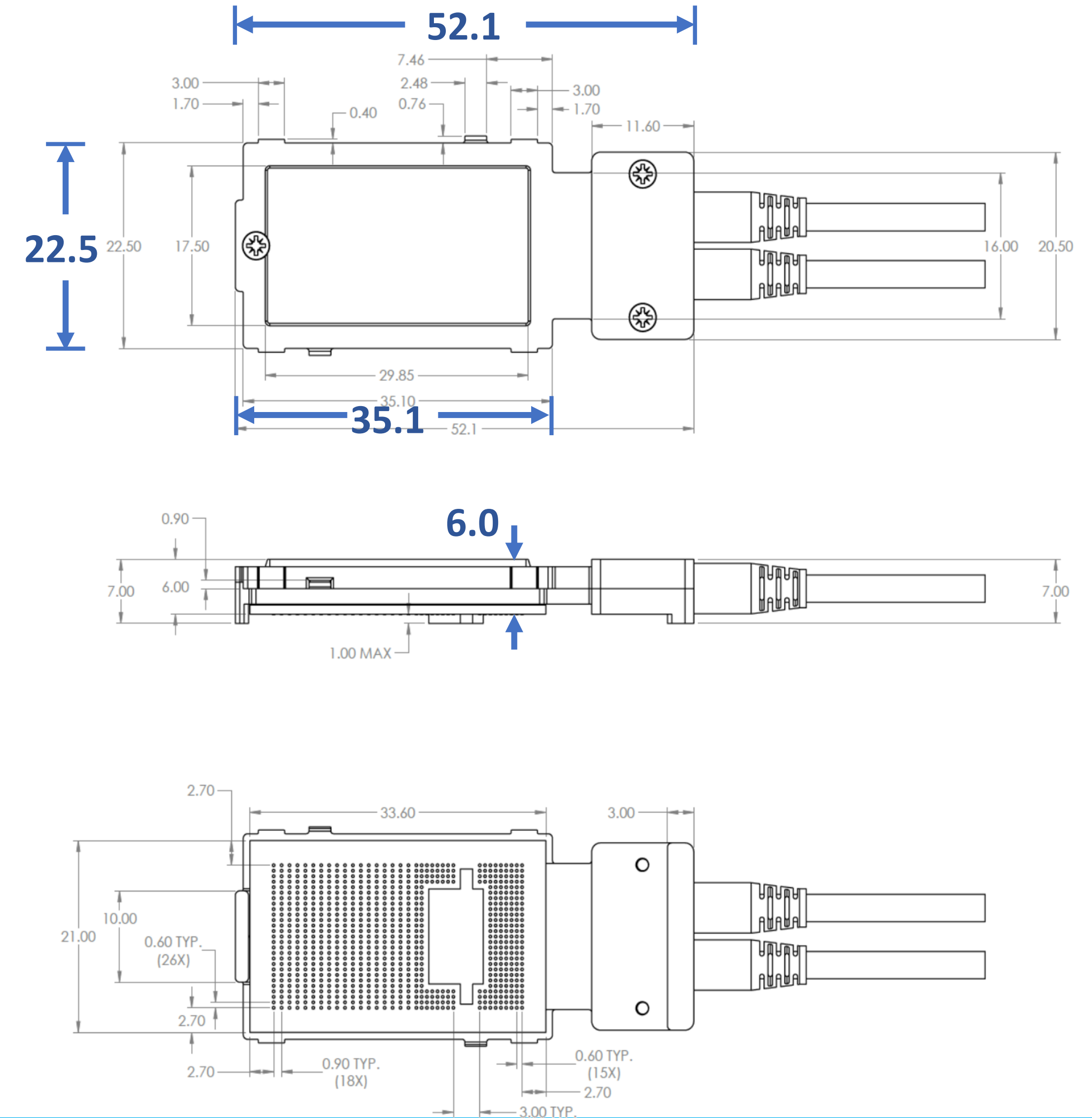
3.2T Module Dimensions

3.2T Optical Module

- 32 x 112G XSR to Standard Optics:
  - 8 x 400G DR4
  - 8 x 400G FR4 (incl. 200G mode)
- Copper Cable Assembly compatible
- Power capability:
  - 56W (Internal Laser option)
  - 48W (External Laser option)



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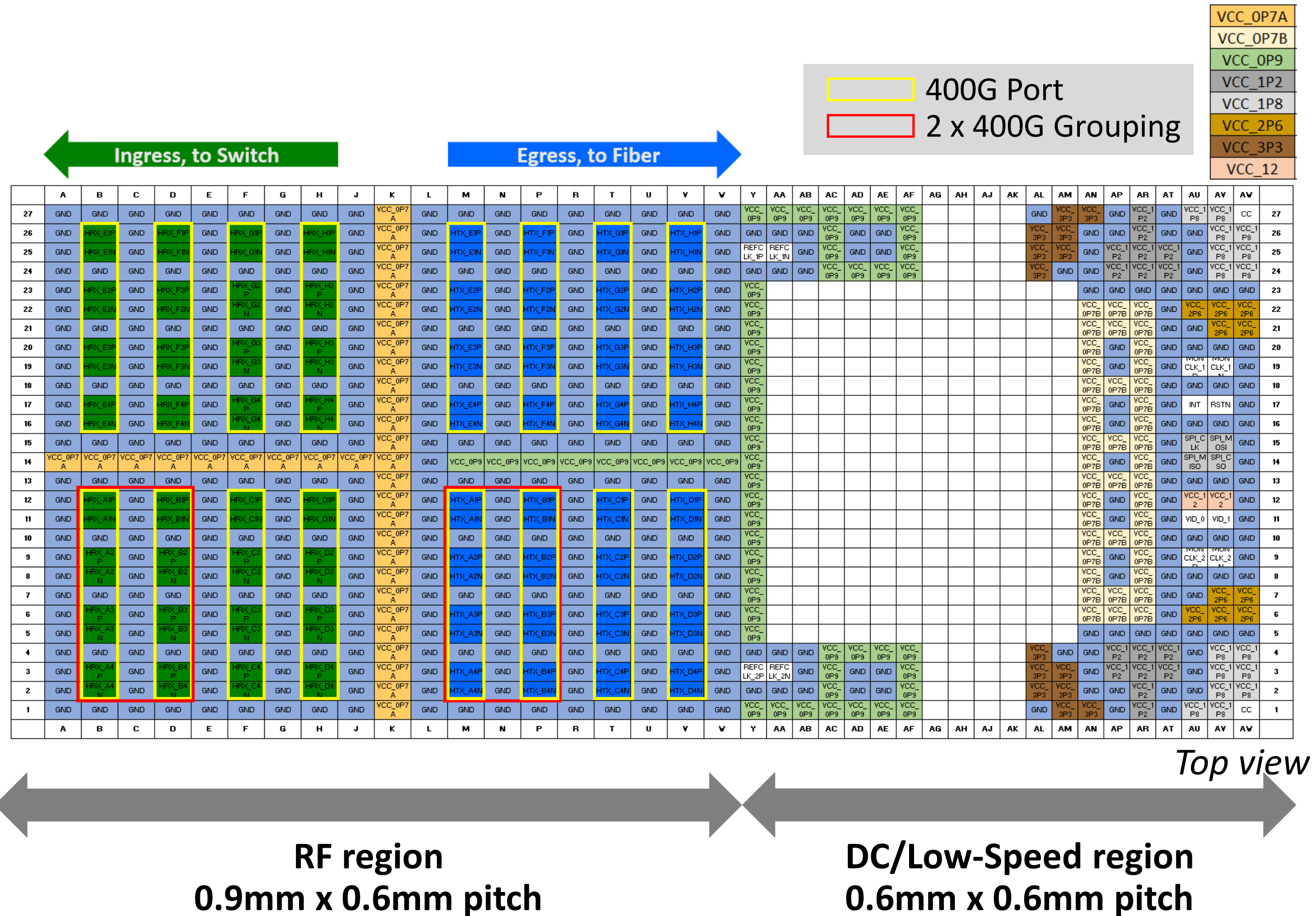
LGA Pin Map

3.2T Optical Module

- Supply rails:
  12V, 3.3V, 2.6V, 1.8V, 1.2V, 0.9V, 0.7V
- Comms Electrical: 1.2V SPI
- Comms protocol: CMIS
- 400G and 800G (2x400G) port grouping defined
  - *For low power modes and 2x400G-FR4 cable assignment*



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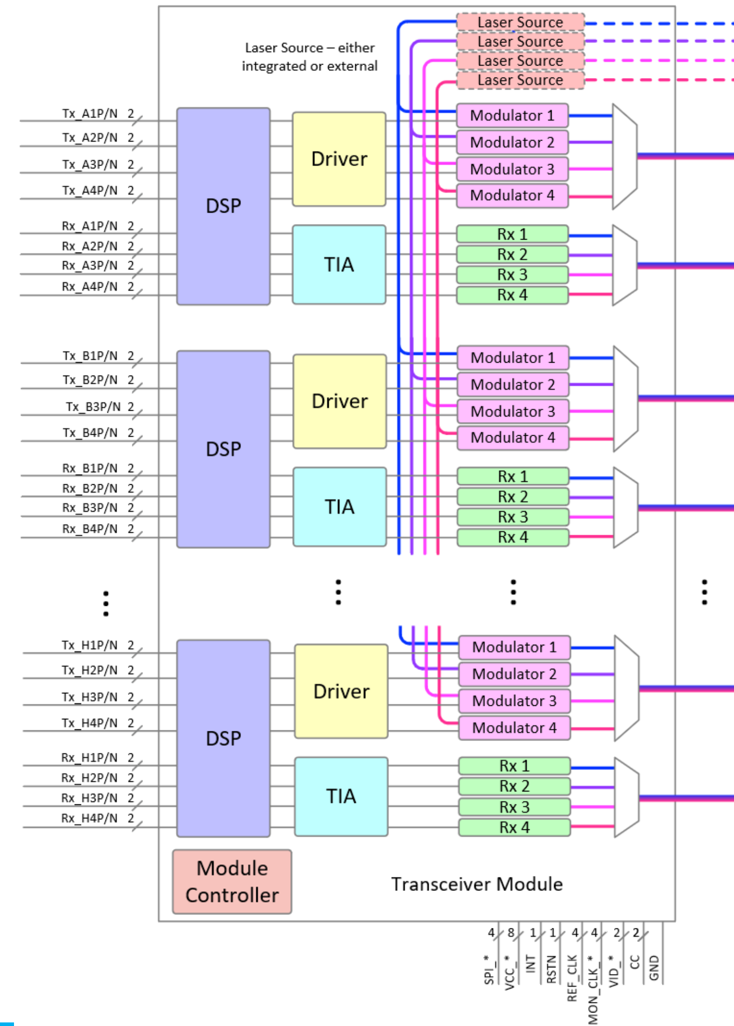
3.2T Optical Module Functionality

3.2T Optical Module

- FR Module example ->

- *How does this all fit in?*
  - *3D integration*
  - *Die/functionality integration*
    - *Optics (Laser + Modulator + PD)*
    - *EIC (Driver/TIA/Control)*



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Why ELSFP?

ELSFP Project

- OIF defining common External Laser Pluggable
- Industry need for co-packaged and near-packaged systems
  - Systems need faceplate density
  - External laser modules need common specification for economies of scale
- Form factor to span multiple system generations
  - Plan for optical & thermal scaling

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External Laser Small Form Factor Pluggable (ELSFP)

Examples: Switches and Special Purpose ASICs

Optical Engines

CPO CPO CPO CPO

Switch

NIC MC MC

CPO

Ethernet

Remote Memory

or

Switch or AI ASIC

ELSFP

ELSFP

SIDE VIEW

Optical Conn

Packaged Laser

DC-DC

µC

ELSFP PCB

ELSFP

ELSFP

- ELSFPs provide CW laser power for optical engines (OEs).
- Decreases thermal power density in the system
- Each large system will likely need multiple (i.e. 8 or 16) ELSFPs
- The light from a given ELSFP can feed more than a single OE.
- A pluggable form factor helps to ensure total system reliability and a “hot swap” replacement if a single laser or ELSFP module fails.
- Eye safety is achieved by a blind mate optical connector internal to the system.

ELSFP

ELSFP

Servers, Linecards, etc.

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Initial Technical Concept

ELSFP Project

Density

- Blind mate pluggable
- Width similar to OSFP (16 modules wide with standard management I/O)

Commonality

- Industry standard 3.3V Supply
- CMIS (Common Management Interface Specification)

Scaling

- Optical Power Classes
- Thermal Power Classes
- Belly-to-belly configurations
- Riding heat sink for system flexibility
- 2 “MT like” ferrules for future proofing
  - Support for 8 PM fibers per MT
  - Support for multiple OE modules

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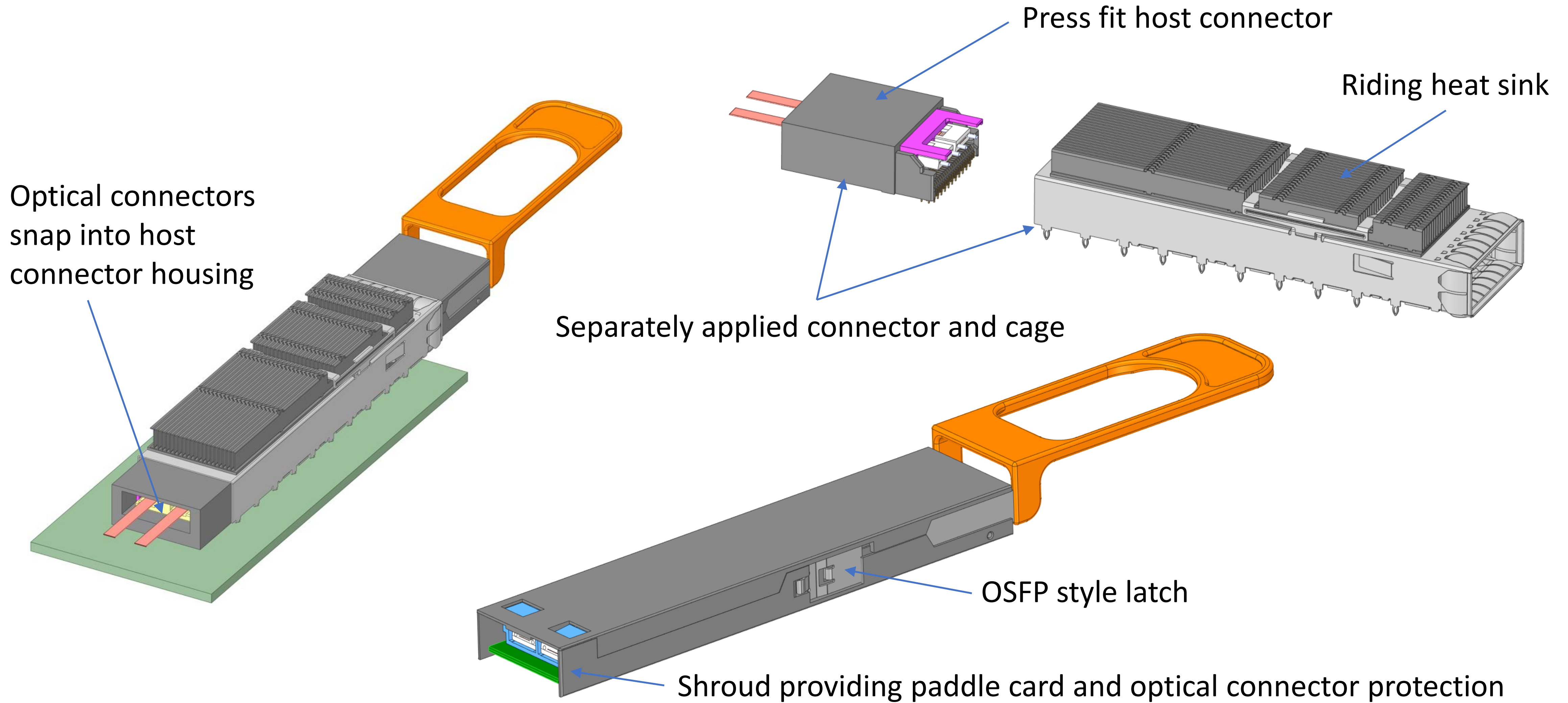
Single Port ELSFP Design

ELSFP Project



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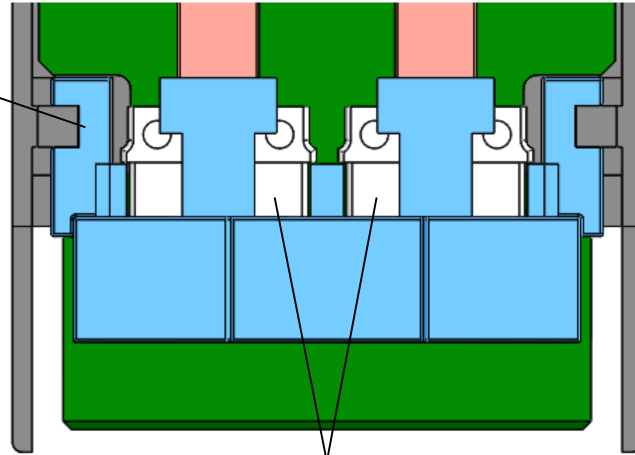
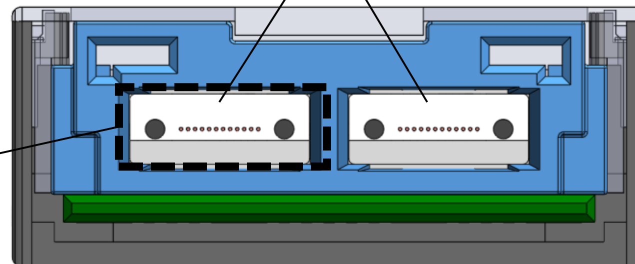
ELSFP Module-Side Optical Connector

ELSFP Project

Connector-to-Module Attachment (Optional)

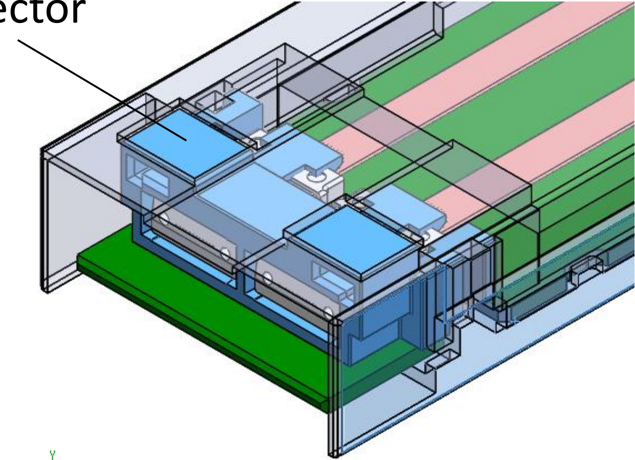


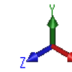
1 or 2 MT-like Ferrules

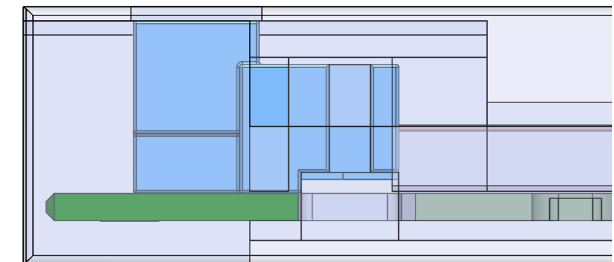


Optional 2nd MT-like Ferrule

Robust anchoring for optical connector







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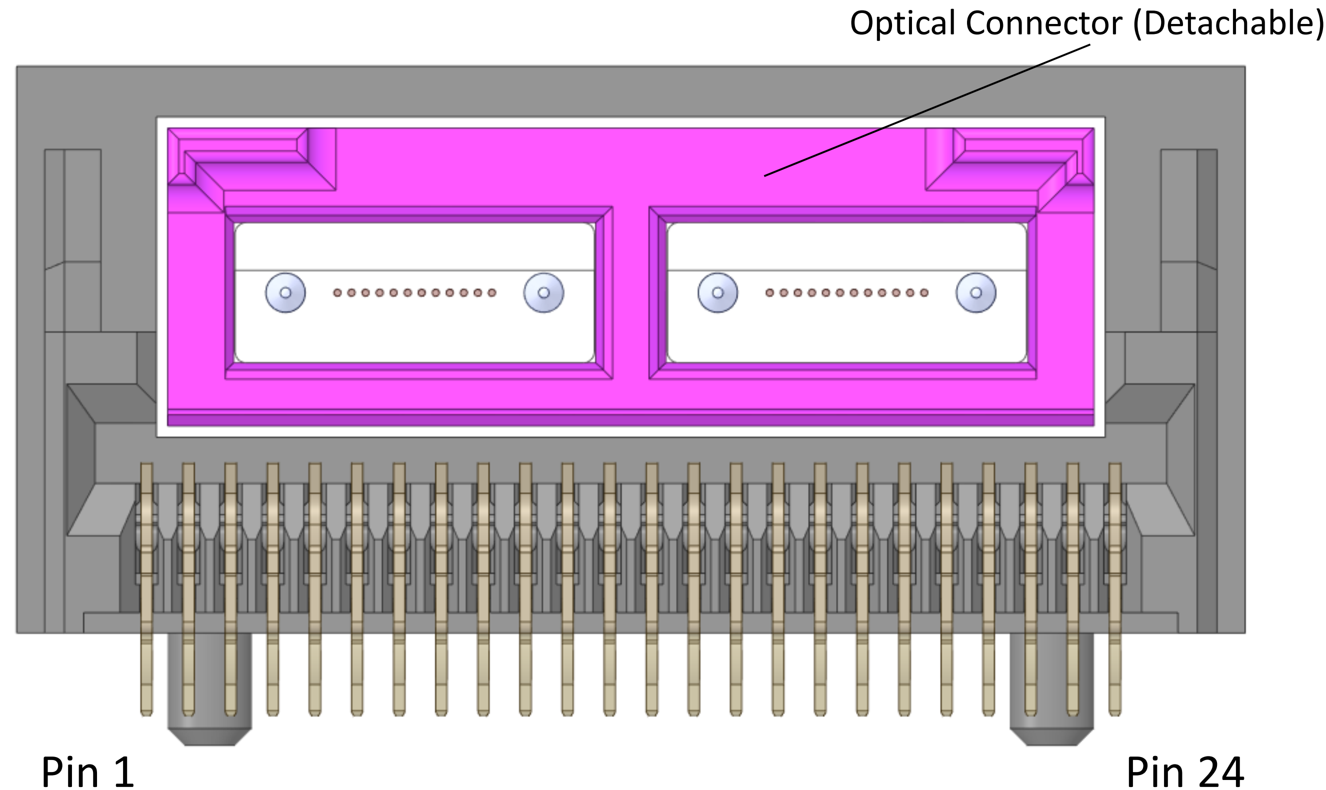
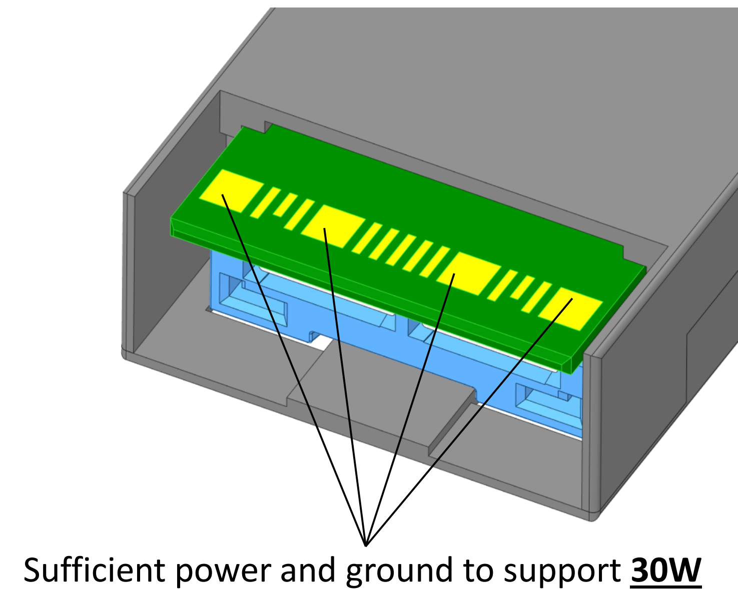
ELSFP Electro-Optical Connector

ELSFP Project



Host side Electro-Optical Connector

Module Bottom side Electrical Contacts



Sufficient power and ground to support **30W**

Additional pins for control/management, laser safety (i.e. presence pin), and spares for future proofing
Optical connector sub-assembly (pink) is separable from the board mounted electrical connector sub assembly

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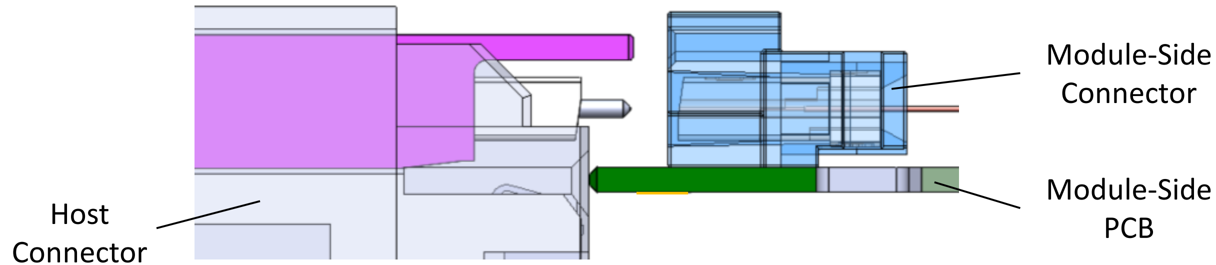
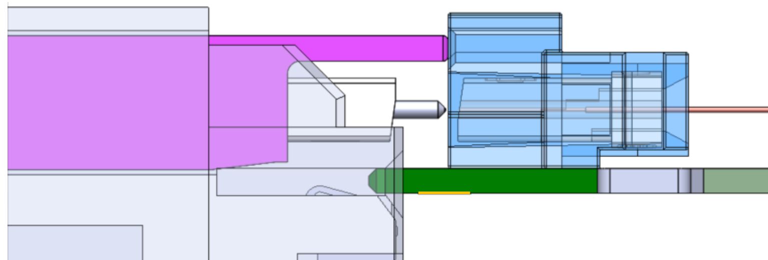
ELSFP Mating Sequence

ELSFP Project

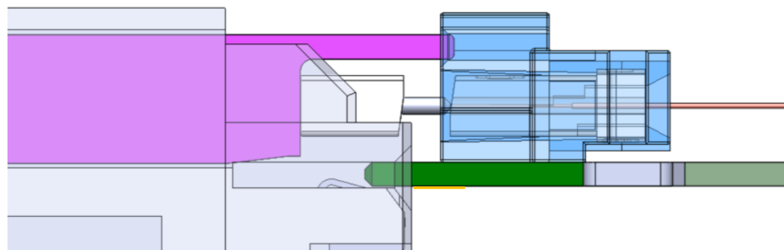
STEP 1: Coarse alignment (PCB-to-host receptacle)



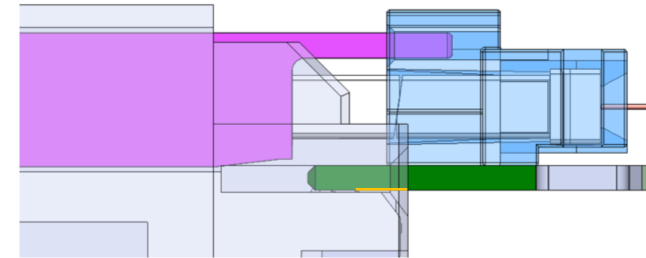
STEP 2: Coarse alignment (Optical coarse alignment pins)



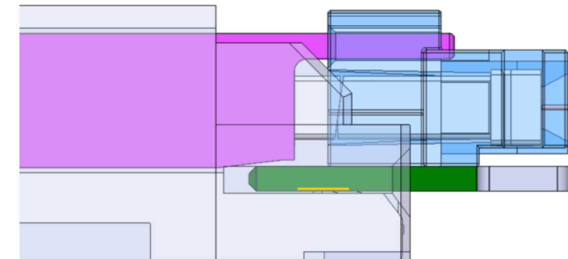
STEP 3: Fine alignment (ferrule guide pins)



STEP 4: Ferrule end-faces in contact



STEP 5: Electrical contact (presence pin)



- Host side optical connector sub assembly has float to enable fine optical alignment.
- PCB and optical coarse alignment pins mate prior to fine alignment of optical ferrule guide pins .
- Ferrule end-faces to contact prior to electrical contact.

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ELSFP Optical Power Classes

ELSFP Project

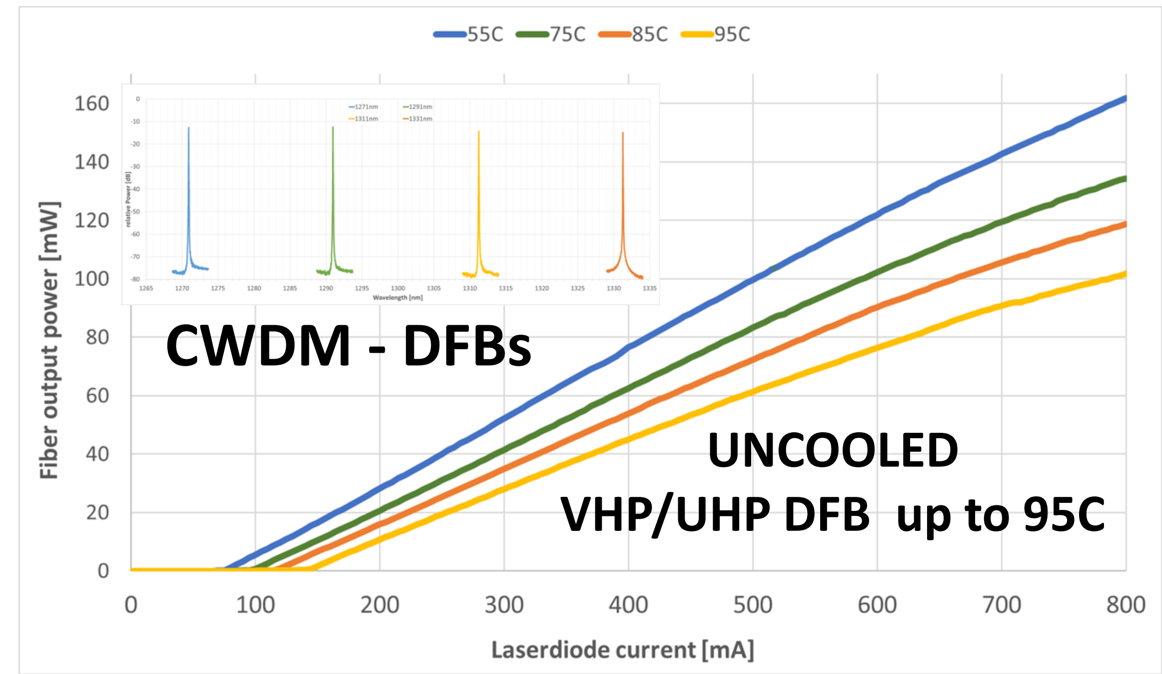
ELSFP Optical Power Classes	Power/λ/Core +/- 1.5dB
Super Low Power - SLP	2dBm
Ultra Low Power - ULP	5dBm
Very Low Power - VLP	8dBm
Low Power - LP	11dBm
Medium Power - MP	14dBm
High Power - HP	17dBm
Very High Power - VHP	20dBm
Ultra High Power - UHP	23dBm
Super High Power - SHP	26dBm

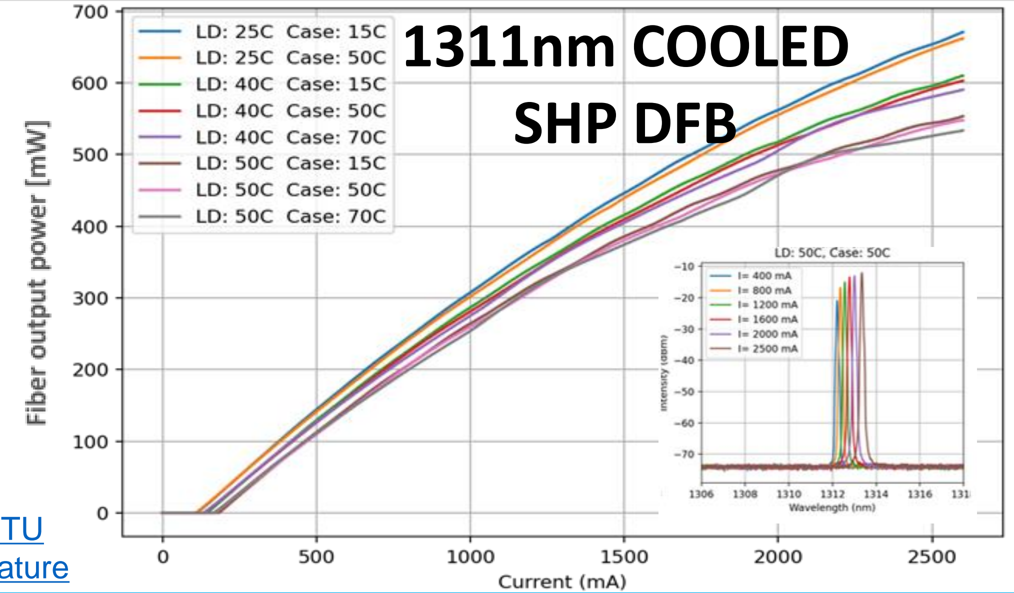
Combs

Single-Channel

Multi-Channel

*Naming convention inspired by ITU Radio Frequency Band Nomenclature





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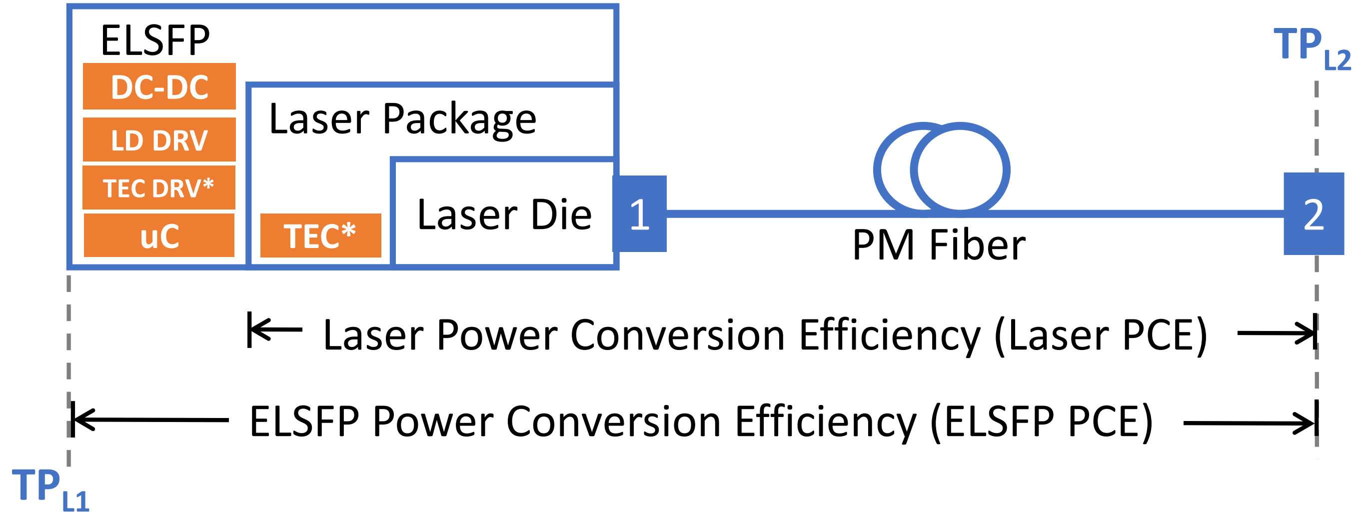
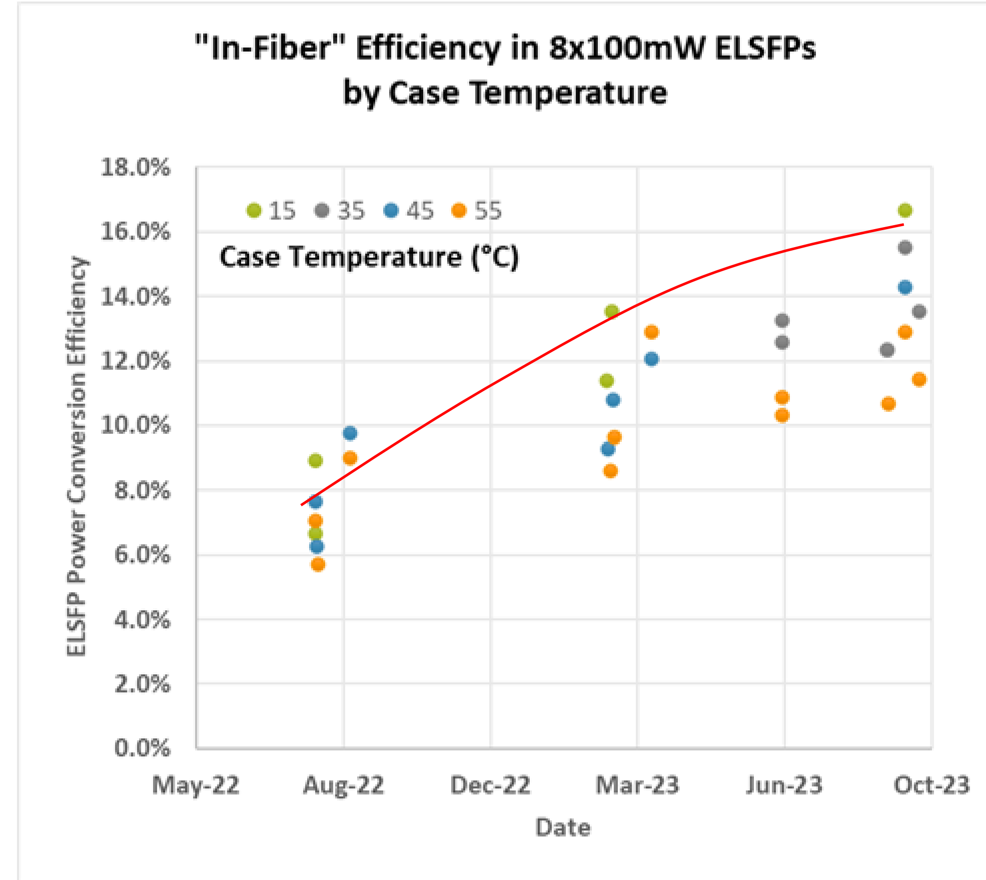
ELSFP's eco-system drives innovation



The ELSFP's eco-system continues to innovate and has yielded impressive improvements in energy efficiency (PCE), a key component of next generation energy efficient interfaces



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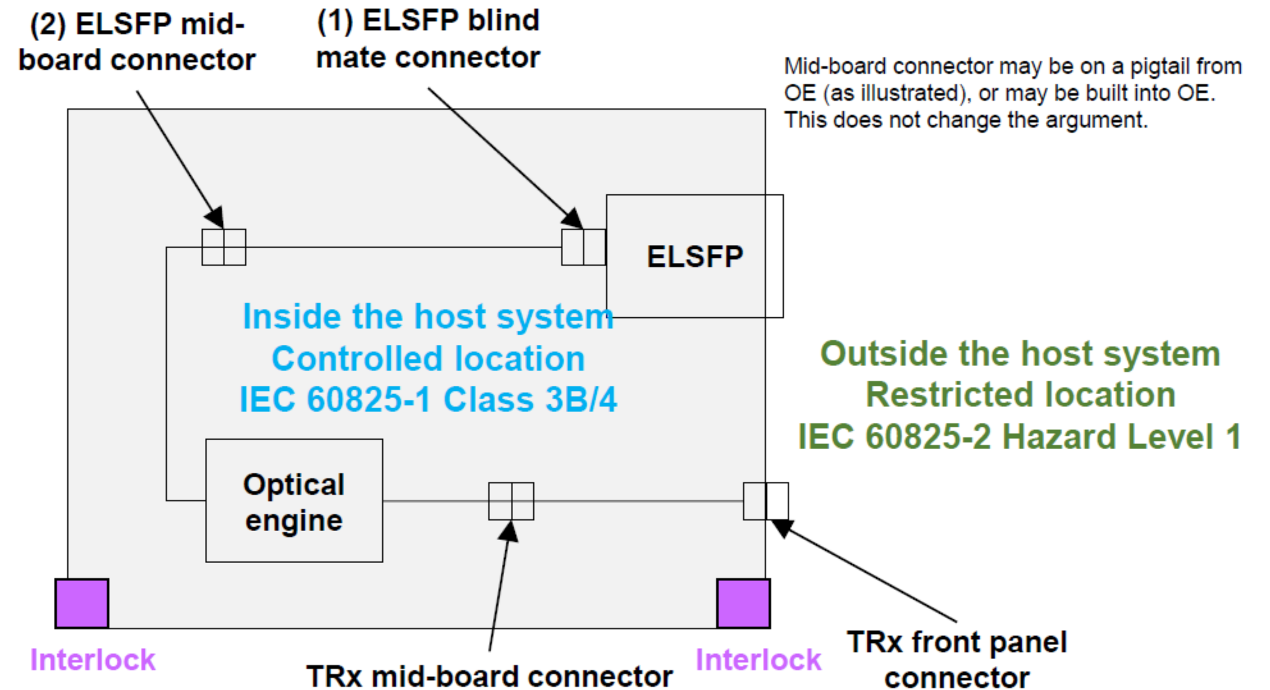
Eye Safety
ELSFP Project

ELSFP's blind mate optical connector paired with a system interlock enables a safer co-packaged system implementation for users.



Similar to EDFAs with powerful CW lasers, Class 3B and 4 lasers can be used inside ELSFP and systems can be deployed in unrestricted locations.

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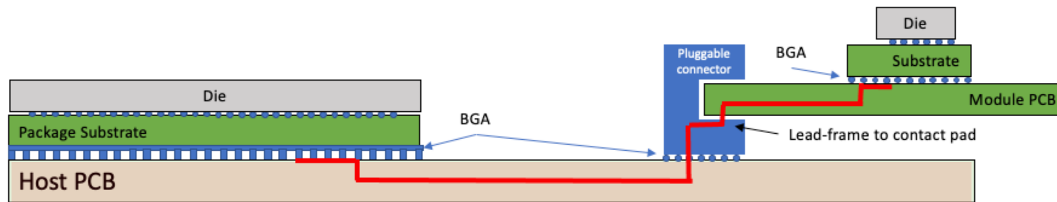
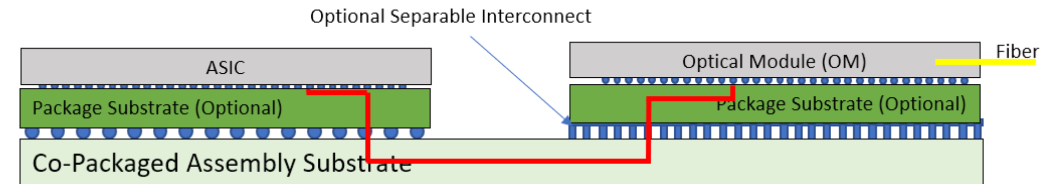
CEI – An Essential Building Block for Co-packaging

Pluggable Module Channel Example Illustration



- Channel loss: 16dB ball to ball (22-24dB bump to bump)
- Typical pluggable connectors: IL of ~1dB with RL of -10dB @26.5GHz

CPO/NPO Channel Example Illustration



- Channel loss: CPO – 10dB bump to bump; NPO – 13dB bump to bump
- Optional separable interconnect performance example: LGA socket: IL of ~0.05dB with RL of -40dB @26.5GHz (*oif2020.341.01, Nathan Tracy*)
- Avoids/reduces major discontinuities.
- Optical modules are not end user pluggable.

- Significant power saving opportunity over VSR to be captured.
- A broad interoperable ecosystem is the key to success and can only be achieved through standardization.

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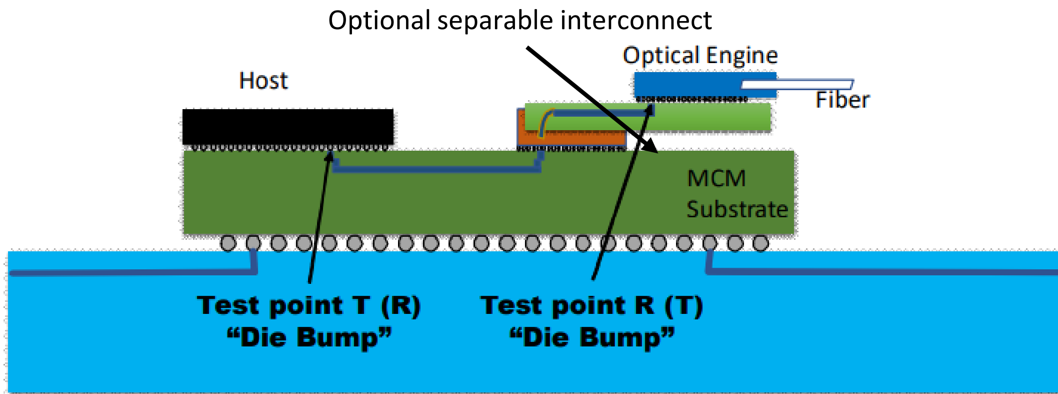
CEI-112G-XSR-PAM4 for Co-packaging



Category	IL at Nyquist (Max, dB)	BER (Max)
CAT1	**10**	**1e-6**
CAT2	10	1e-8
CAT3	8	1e-9

- Baud rates supported: 36 Gsyms/s to 58 Gsyms/s
- Based on loss and jitter budgets between TX and RX using copper signal traces in a SIP(System in a Package) to enable low power consumption
- Three channel categories are defined, allowing optimization for various applications.
- Timeline
  - Project started in April 2018.
  - Draft specification is becoming technically stable. Few pending items to be addressed.

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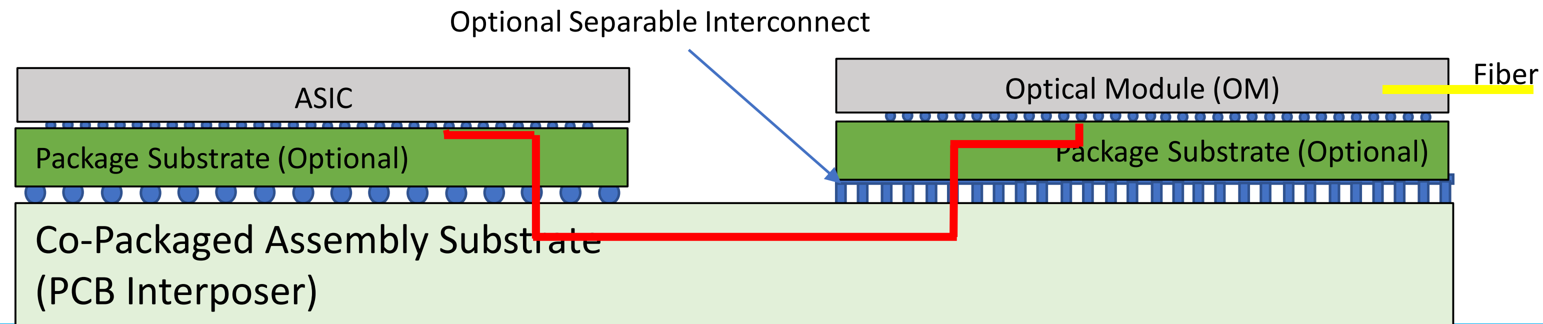
CEI-112G-XSR+ -PAM4 for Near Packaging

- The emergence of Near Package Optics (NPO) Architecture
  - Co-packaging requires significant package substrate size increase and technology advancement, which adds risk to goals of availability, cost and multi-vendor support.
  - Instead of a monolithic package approach, Near Packaging relies on advanced PCB technology for dense high-speed routing without significant power penalty.
  - Near Packaging architecture takes advantage of existing technologies and more robustly enables an open ecosystem implementation.
- Additional margin also strengthens a broader supply base for co-packaging implementation and adoption.
- Baud rates supported: 36 Gsyms/s to 58 Gsyms/s
  - Optimize for Ethernet rate @ 106.25Gbps – the key application for CPO/NPO
  - Insertion loss < 13dB @ 26.5625GHz Nyquist bump to bump with up to 1 separable interconnect.
- Enable the lowest practical energy consumption (pJ/b) implementation.
- Leverage specification methodology and other work from existing CEI 112 projects.



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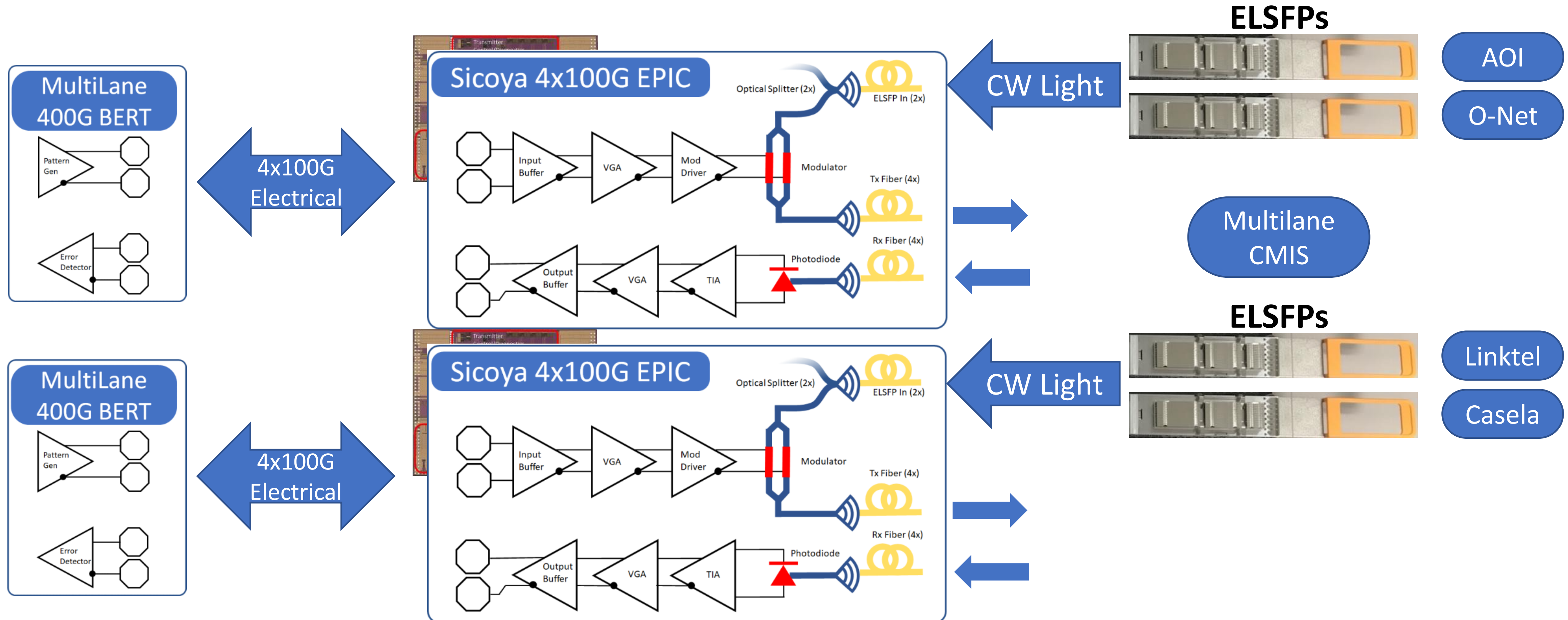
Joint Co-Packaging ELSFP & CEI Linear Interface

Interoperability Demonstrations



Tx Optical Path: ELSFP → PM Fiber → 1:2 Optical Splitter → MZ Modulator → SM Fiber
Tx Data Path: 100G PAM4 BERT → 10dB Loss → Linear MZ Driver → MZ Modulator
Rx Data Path: SMF → Photodiode/Linear TIA → 10dB Loss → 100G PAM4 Error Detector

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Joint Co-Packaging ELSFP, CMIS Interface, & Linear

Interoperability Demonstrations

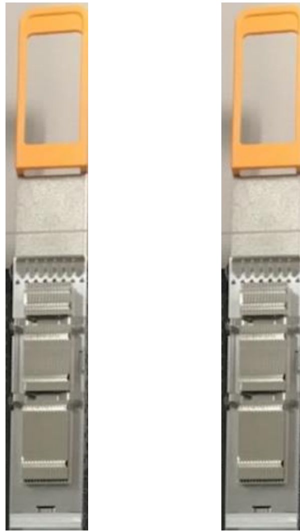
ELSFPs
AOI, O-Net

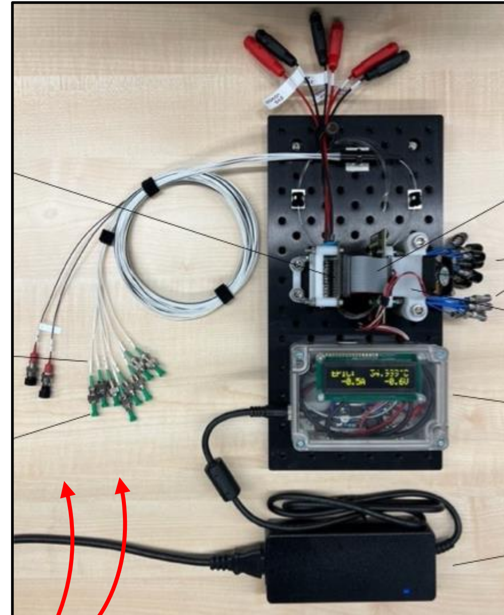
CEI-Linear
Sicoya

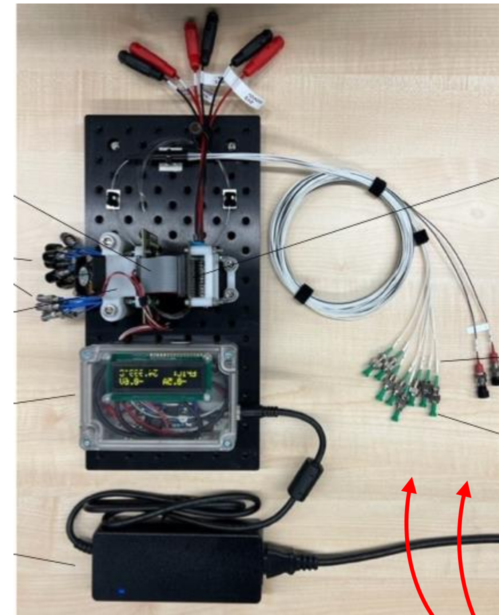
CEI-Linear
Sicoya

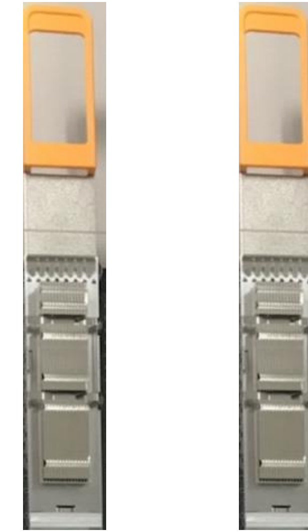
ELSFPs
Linktel, Casela

Management I/F
CMIS

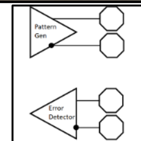




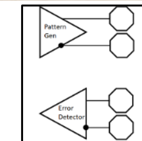




Management I/F
CMIS



Multilane
400G BERTs



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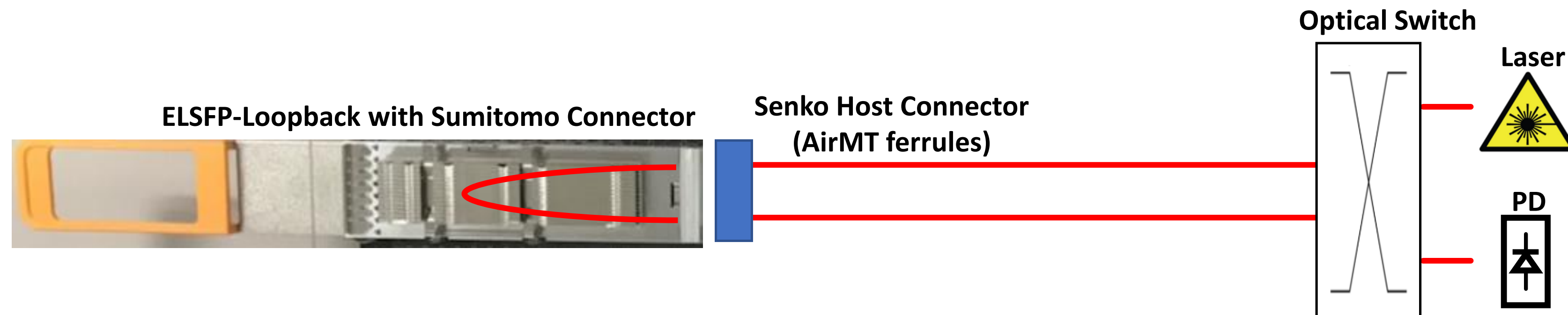
Blind Mate Connector Interop with Loop-back ELSFP

- Senko connector mated with Sumitomo connector, and vice versa
- AirMT ferrules in the blind-mate connectors
- Measurement shows insertion loss through two blind-mate connectors



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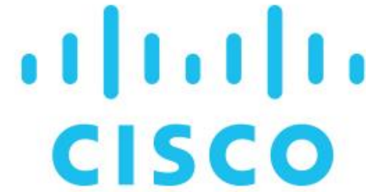

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