CPO Optical Connectivity Selection

Density
- Fibers per 1RU panel
- Insertion Loss
- Return Loss
- Connector components

Performance
- Fibers per Connector
- Other
- Termination Tooling
- Cleaning & Inspection

Granularity

Ecosystem

Proprietary and Confidential
Density vs Granularity

- **Density** = Number of optical fibers that can fit in 1RU (for a given connector type)
  - 51T switches will require 256f for FR and 1024f for DR, but front panel also requires real estate for other components (e.g. ELS, airflow, LEDs)
  - Strawman: Assume 50% of front panel dedicated to optical connectors

- **Granularity** = Number of optical fibers per connector
  - Connectors with one row of fibers simplify installation/polarity
  - Strawman: Assume one row of fiber per connector (e.g. MPO16)
Density vs Granularity Tradeoffs: 51T Switch Example

Connector Density (# fibers per 1RU) vs Connector Granularity (# fibers per connector)

- FR (100%)
- FR (50%)
- DR (100%)
- DR (50%)

Connectors shown:
- SC
- LC
- MDC
- MPO-12
- MPO-16
- MPO-24
- MXC-16
- MXC-32
- MMC-16
Demo is half pluggables & half CPO

- Overall front panel real estate is comparable between pluggable & CPO
- Majority of CPO real estate is ELS modules
- Optical I/O may require new high density connectors

Takeaway: New VSFF high density connector (MMC) enables same 256f count in a fraction of the space.
Density Considerations: New, Very Small Form Factor (VSFF) Connectivity Solutions

Keyed to prevent MMC/MDC mating

MMC: VSFF Multi-Fiber; Reduced size MT-style ferrule technology

MDC: VSFF Duplex; Based on 1.25mm ceramic/LC ferrule technology

- 16 fibers at 250 micron pitch
- Compatible with 250, 200, and 165 micron fibers
- Intermateable with MT technology

TMT / MT Ferrule Compatibility
SMF Expanded Beam

- SMF performance approaching PC connectors
  - IL < 0.50dB, RL > 55dB
- Density comparable to MMC
- Supports higher fiber count connectors
  - Same low spring force independent of fiber count
- Easier to install & service
  - Large spot size less sensitive to dust (by factor of ~25x)
- Leverages mature MMF variant (millions deployed)

Source: COBO, Optical Connectivity Options for 400 Gbps and Higher On-Board Optics, 2019
ELS connectivity identified by Broadcom as an innovation opportunity

- Largest driver of ELS connector thought to be power density
- Expanding the beam reduces power density (by factor of ~25x)
- Encouraging initial results inserting PM fiber into PC array connectors
- Encouraging initial results with high power SMF through expanded beam connector
- More study needed with focus on optimization and manufacturability
- More study needed to define acceptable threshold for “debris in the laser path”
SMF Expanded Beam: Enables Separable Connection at Optical Engine

- Optical separability may be a requirement for future engines that are soldered to switch host PCB
- Prevents relatively low-reliability fiber from being permanently attached to high-dollar ASICs
- Both edge-emitting and surface-normal (see right) being studied

Source: COBO, Design Considerations of Optical Connectivity in a Co-Packaged or On-Board Optics Switch, 2022
### Performance Considerations

<table>
<thead>
<tr>
<th>Connector Parameter</th>
<th>SMF Physical Contact (e.g. MPO, MMC)</th>
<th>SMF Expanded Beam (e.g. MXC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss</td>
<td>≤ 0.25dB*</td>
<td>≤ 0.50dB</td>
</tr>
<tr>
<td>Return Loss</td>
<td>&gt; 60dB</td>
<td>&gt; 55dB</td>
</tr>
<tr>
<td>Technology Maturity</td>
<td>20+ years (Billions deployed)</td>
<td>Emerging**</td>
</tr>
<tr>
<td>Sensitivity to Dust</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Dependence on Cleaning</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Spring Force</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Power Density</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

* Industry pursuing path to even lower losses ("Grade A")
** Leverages decade of MMF expanded beam deployment (millions of ports)
Ecosystem Considerations: Application/Link Design

VSFF & Expanded Beam offer scalable multi-port options, including:
- Mid-board connectivity
- Backplane connectivity
- Ganged insertion

Ganged Insertion/Removal Hardware
Ecosystem Considerations: Scaling the Supply Chain

More than just the connector
- Termination Tools
- Polishing Fixtures
- Cleaning & Inspection
- Installation Tools
- Hands-on Training

Scale a Global Industry
- Dozens/hundreds cable assembly houses
- Multiple geographies
Summary

1. Density & Granularity
   - Emerging SMF connectors to address CPO needs
     - Physical Contact (e.g. MMC)
     - Expanded Beam (e.g. MXC)

2. Performance
   - Designed for next-generation links
     - Physical Contact meets ultra low loss requirements
     - Expanded Beam closing the gap

3. Ecosystem
   - Much more than just the connector itself…
     - Portfolio of options enabling connectivity at front panel, mid-board, optical engine, & backplane
     - Goal is connector manufacturers to train/rampSCALE a global supply chain

4. Expanded Beam
   - Alternative to physical contact
     - Eases installation and enables blind mate connections
     - Significantly reduces power density, which may be promising for ELS connections
Thank you!

Tom Mitcheltree
Advanced Technology Manager

(828) 323-8883
tomitcheltree@usconec.com