Flexi Circuit Fiber Shuffle – Interconnect Solution for Inside Chassis

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Introduction

• Design considerations on fiber management inside data center chassis
• Flexi-circuit fiber shuffles – The next enabler of CPO switches and systems!

Optec Technology Limited

• Fiber optic cable assembly and interconnect solution
• Founded 2001
• COBO member since 2017
Riddle

Can you connect A → A, B → B, C→C without crossing lines?

Answer at the end of presentation.
Fibers in CPO System

CPO = Co-packaged Optics

Citation:
Board Level Fiber Connectivity

*Blue indicates where fibers exist

- **COBO** (Consortium of On-Board Optics)
- **CPO** (Co-packaged Optics)
- **OE** (Optical Engine)
- **PMD** (Physical Medium Dependent)
- **MDI** (Medium-Dependent Interface)
- **I/O** (Input/Output)
- **PC** (Physical Contact)
- **VSFF** (Very Small Form Factor)
- **AG** (Air Gap)
- **EB** (Expanded Beam)
- **ELS** (External Light Source)
- **SMF** (Singlemode Fiber)
- **MMF** (Multimode Fiber)
- **PMF** (Polarization Maintaining Fiber)

**Flexi Circuit Fiber Shuffle!**
Conventional Patching

- Conventional Patching of Switches with Pluggables

Example:

- More connectors in the link
- More rack space required

**Consideration:**
- Can we pre-build some or all of these patchings inside the switch?
- Too many cables for a small box?
Why Fiber Shuffle?

- Possibility of CPO switches with fiber shuffle built inside chassis

Example:

- Cross connect happens within CPO switch with optimized number of connectors per link
- Channelings are pre-configured, fabricated & tested at factory, protected in the switch box
- Simple Data Center cabling; Saves rack space and OpEx!

✓ Fiber Mapping
✓ OE Redundancy
✓ Simplified Cabling
Fiber Shuffle

• Re-configure fiber arrangement from origin ports to destination ports
• Different types of connectors can be used within the shuffle
• It facilitates
  • Fiber mapping
  • Redundancy
• Forms of fiber shuffle
Fiber Mapping

Fibers from an OE is mapped out to 4x FP connectors

e.g.
3.2TB OE with 2 connectors (1x32Tx +1x32Rx) can be mapped out to 4x 800G I/O with 4x 16F (8Tx & 8Rx) connectors at FP

- Transfer bigger granularity into smaller through Fiber mapping
- Smaller granularity means better reliability /redundancy when a I/O port or a fiber fails
Redundancy

OE Redundancy
Each port is connected to more than one OE.

- Connection to more OE means better system reliability / OE redundancy.
- At failure mode, an I/O port is still connected to 3x OEs when an OE is having a problem.

e.g., 800G I/O with 8 lanes of 100G signals from 4 OEs
1x16F (8Tx & 8Rx) connector at Front panel are connected to 4x OEs using 2Tx+2Rx fibers.
Fiber Shuffle Interconnect OE – MB - FP

Schematic Diagram

Fiber Mesh
Up to 16x OEs in a Switch.
The diagram illustrates 4x OEs
Fiber Routing Concerns Within Chassis

• Highly compact space within chassis
• Cable congestions if cables are being put inside chassis
• Need a dedicated way to manage hundreds to thousands of fibers
• Airflow
• Effect of system environment to the cable assemblies long term reliability, e.g. temperature and vibration
• The form of fiber routings shall be operation friendly for chassis assembly
**Flexi Circuit**

- Fibers are being laminated on a flexible thin film substrate
- Fibers intersect on the thin film with optimized amount and protection
- Well controlled bending angle according to fibers min. bending radius
- Layers are stackable, allowing better fiber management
Flexi Circuit Fiber Shuffle For CPO Switch Demo

For \(\text{Tx/Rx}\) fibers,
- Typical SMF count /connector: 8F, 16F, 32F
- Max number of connectors: 32
- Max SMF fiber count: \(32 \times 32 = 1024\)F

For \(\text{PMF-ELS-OE/ASIC}\) Interconnection,
- Typical fiber count /connector: 2F, 4F, 8F
- Max number of connectors: 16
- Max fiber count: \(8 \times 16 = 128\)F

Total 1152F

- Optical fibers being laminated on **flexible thin film** substrates
- The films are **stackable** for multi-layer design

Backplane Adaptor Interface for ELS (External Light Source)
- Blindmate Connector at ELS
- MMC®-16 – Very Small Form Factor MT Connector
Manufacturing of Flexi-Circuit Fiber Shuffle

• Scalability
• Polarity control

Automated Fiber Laying Machine

Semi-Automated Fiber Routing Machine
# Design Considerations of Fiber shuffle

<table>
<thead>
<tr>
<th>Areas</th>
<th>Key Considerations</th>
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</thead>
<tbody>
<tr>
<td>MB – Mid-Board</td>
<td>Connector Interface, Connector location, Polarity</td>
</tr>
<tr>
<td>FP – Faceplate</td>
<td>Connector Interface, Port Assignment, Polarity</td>
</tr>
<tr>
<td>Fiber Type</td>
<td>Fiber Count, Fiber Mode, Bending Radius, Fiber OD</td>
</tr>
<tr>
<td>Shuffle Location</td>
<td>Preferred shuffle location, Mounting Mechanism, Fiber routing, Avoid SMT components on PCB</td>
</tr>
<tr>
<td>Other</td>
<td>System temperature range, Air Flow/ Cooling Method, System assembling workflow, Serviceability at failure mode</td>
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Choice of Fiber

### Dimensions

<table>
<thead>
<tr>
<th>Typical Size</th>
<th>250um Fiber</th>
<th>200um Fiber</th>
<th>Reduced Cladding Fiber</th>
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<tbody>
<tr>
<td>Core</td>
<td>SM: 8-9um</td>
<td>MMF (OM2-5): 50um</td>
<td></td>
</tr>
<tr>
<td>Cladding</td>
<td>125um</td>
<td>125um</td>
<td>80um</td>
</tr>
<tr>
<td>Bare Coating</td>
<td>250um</td>
<td>200um</td>
<td>165um</td>
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</table>

### Fiber Mode

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>MMF</th>
<th>MMF SWDM</th>
<th>SMF</th>
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<tbody>
<tr>
<td>G.652D, G657A1, A2/B2, B3</td>
<td></td>
<td></td>
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<tr>
<td>Wavelength (λ)</td>
<td>850, 1300nm</td>
<td>850~953nm</td>
<td>1310, 1490, 1550, 1625nm</td>
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### Min. Bending Radius for SMF (mm)

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<th></th>
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<tbody>
<tr>
<td>r=30</td>
<td></td>
<td>r=10</td>
<td>r=7.5</td>
<td>r=5</td>
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</table>
### Choice of Optical MDI at Faceplate:

**Optical Media Dependent Interface**

<table>
<thead>
<tr>
<th>Granularity</th>
<th>Physical Contact</th>
<th>Air Gap</th>
<th>Expanded Beam</th>
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<tbody>
<tr>
<td>2</td>
<td>Conventional</td>
<td>VSFF</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Duplex LC CS SN MDC</td>
<td>AirMT-12</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>MPO-12 SN-MT 16 MMC-16</td>
<td>SN-EB MM MXC-1x16</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>MPO-24</td>
<td>AirMT-24</td>
<td>MM-MXC-2x16</td>
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<tr>
<td>32</td>
<td>MPO-32</td>
<td>Roadmap</td>
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**Considerations:**
- Density
- Performance
- Durability
- Ease of operation
- Blind Mate possibility

*Photo courtesy: US Conec Ltd; Senko Advanced Components*
Flexi-Circuit Fiber Shuffle Demo

• Example of a few considerations
  
  1. To improve airflow in middle → use flexi-circuit fiber shuffle and moved connector to the side

  2. Increased density on front panel → used SN-MT connector in front panel

  3. Used 200um reduced cladding fiber (RCF) for higher density and connector consideration
Other Applications of Flexi-Circuit Fiber Shuffle

Optical Backplane

Board-to-Card

Chips-to-Chips
Riddle -

Can you connect A → A, B → B, C → C without crossing lines?

Just a few solutions…

- Shortest total link
- Same orientation
- Same length

Every detail means a better design
Involve Interconnect Solution Designer Earlier!