Fibre optic connectors – a different “view”

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Presentation Outline

1. Alignment and Insertion Loss
2. Overview of Optical Fibre Connectors
   - Standard connectors
   - Multiple fibre connectors
   - Rugged connectors
   - Active optical cable assemblies
3. Active multiple channel connectors
Attenuation

Insertion Loss \( = -10 \times \log \left( \frac{P_t}{P_o} \right) \)

Return Loss \( = -10 \times \log \left( \frac{P_r}{P_o} \right) \)
Return Loss

• **PC (Physical Contact):**
  – Low Insertion Loss (0.2 dB typ.)
  – Return Loss:
    • Mated > 45 dB
    > 55 dB (Ultra PC)
    • Un-mated ~ 15 dB

• **APC (Angled Physical Contact):**
  – Low Insertion Loss (0.2 dB typ.)
  – Return Loss:
    • Mated: 70..80 dB typ.
    • Un-mated: > 60 dB
SC Connector

- Subscriber Connector, Square Connector, Standard Connector
- Push pull connector
- Pre-Radiused, Full 2.5 mm Ceramic Ferrule
- Tuneable, 4 positions for Lowest Losses
- PC or APC end facet
- Multimode or Single mode
- Simplex & Duplex Versions
- Wide Range of Cable Diameters
- 900 μm buffer
- 1.6 - 2.0, 2.4 & 3 mm
- Polymer and Metal rear body design
- Standards IEC 61754-4, TIA/EIA 568B & GR326
- Applications: Telecom, Datacom, CATV, Industrial
LC Connector

- Lucent Connector or Local Connector
- Small Form Factor (SFF), push pull connection
- Reduces equipment space by 50%
- Full 1.25 mm Ceramic Ferrule
- RJ 45 based design
- PC or APC end facet
- Multimode or Single mode
- Simplex & Duplex Versions
- Field installable duplex clip
- Secure Versions (Colour & Key coded)
- Standard IEC 61754-20
- Applications: Computer & Transmission Equipment Manufacturers, Telecoms, Industrial, High-density connections, SFP transceivers, XFP transceivers.
Ultra-short LC

- Ultra Short LC design (37 mm) when standard LC is 52 mm
- Accommodating cable diameter 1.8 - 2 mm
- Shortest design
- Single mode and Multimode
- Separate Simplex & Duplex thumb latch
- Bend Limiting Boot
  - Preventing signal losses due to sharp cable bends / kinks
- Applications
  - Front I/O cabling
  - Racks with Front doors
  - Restricted Space Areas
Variety of designs for all applications

- Short 42 mm boot
- Low Cost
- Angled
- Short Buffer
- Bend Limiting
- 3.0 mm Cable
- Right Angle
- Bend Limiting Buffer
MU Connector

- Miniature Unit
- Half the size of the SC Connector
- Push Pull design
- Full Ceramic 1.25 mm Ferrule
- PC end facet
- Single mode
- Tuneable
- Primarily used in Asia
- Standard IEC 61754-6
- Applications: Telecom, CATV, Data
FC Connector

- Ferrule Connector or Fibre Channel
- Threaded coupling nut for secure connection
- Single Piece Rugged Connector Body
- PC or APC end facet
- Full Ceramic Ferrule, 2.5 mm
- Single mode or Multimode
- Standard IEC 61754-13
- Applications: Datacom, Telecom, single-mode lasers, CATV, Instrumentation, Widely used eg. UK & Indian Telecom Networks
ST Connectors

- Straight Tip
- Bayonet connection
- Only PC end facet
- Multimode or rarely Single mode
- Ferrule options: Full Ceramic, Stainless Steel (SS), Polymer
- Different Hole size options in SS:
  - 125, 140, 231, 240, 280 μm
- Nut options: Stainless Steel, Polymer
- Standard IEC 61754-2
- Applications: Industrial, Military, Medical
MT Connector

- Mechanical Transfer
- Push pull connection
- 2.5 mm × 6.4 mm
- Two alignment pins
- Available in pre-terminated cable assemblies
- Applications: outdoors
MPO/MTP and MPX Multi-Fibre Interconnects

- Multiple Fibre Push On/ Pull Off
- Push pull connection
- Free floating for system reliability
- Based on industry proven MT technology
- Blindmate backplane solution
- Both multimode (62.5/125 μm or 50/125μm) and single mode (9 μm) fibre
- Standard IEC-61754-7
- Applications: indoor interconnects
PARA-OPTIX™ Cable Assemblies

• Industry Standard MTP/MPO Connector
• Up To 72 Fibres
• Multimode Only
• Use Anywhere MPO Is Used:
  – Backplane
  – Front-panel I/O
• Telcordia Testing
  – 501-626 Test Report
Rugged Fiber Optic Connectors

- Fiber
- Ball lens
- Expanded Beam Connector
Sealed Industrial Rugged ODVA Compliant Duplex LC

- IP67 Rated - Protection from dust and water immersion
- LC qualified to Telcordia GR-326 and TIA/EIA 568B.3
- Temperature – 40 to 85°C
- Bayonet-style mechanical lock
- Flame retardant UL 94 V-0
- Redundant interfacial, cable, and panel seals
- Single mode and multimode fibre
Outdoor Connector

- Fibre Optic Cable assembly with an industry standard copper interface
- Easy to Install
- One hand blind mating possible
- Easy to clean
- Waterproof
- Dustproof
- Corrosion resistant
- EMI Shielded.
- IP 68
- Light Weight
- Low Cost
- Low Insertion Loss
- Longer Reach

Duplex Version

Quad Version
Outdoor IP67 Sealing System: FULLAXS

Applications
- Fiber To The Antenna
  - Remote Radios
  - BTS
- Industrial
- Other Outdoor applications

Features & Benefits
- „Open“ Bulkhead: Easy direct access to SFP access for repair or upgrade
- Bayonet Locking, IP 67 Sealing: Quick & Easy handling returns Low Applied Cost
- No internal pigtail required for coupling to SFP: Reduces System Cost
- Based on standard LC platform: Proven interface & wide range of SFP TxRx’s
- Free Z-Axis with full float: Accepting all known SFP’s, No stress on Fibers & Cable
- Easy Bulkhead (X-Y) Positioning: Allows wide tolerance on SFP position
- Will also accommodate RJ45 etc.: One System fits all
Imagine…. Having one of the following problems

- Real estate of present location is full and needs to be expanded
- Cable lengths would need to exceed 50 m
- Costs for new real estate would be too high
- EMI of all cables would exceed limits
- Too much cable weight
- Air flow problems
- Forced cable bending

\[ R_1 = 25 \text{ mm} \ll R_2 \]
Active Optical Cable Assemblies

- Applications:
  - Super Computers
  - Cluster Computers
  - High End Servers
  - Mass Storage
  - Metro Network Switch / Cross Connect
  - High End Carrier Class Routers
PARALIGHT Active Optical Cable Assemblies

- Optical Fibre with electro-optic components
- No Equipment Upgrades
- Functions like a Standard Electrical Cable
- 100 Metres Plus Reach
- Low Latency
- No EMI
- Hot Pluggable
- 1/3 Size of Copper Cable
- 1/10th weight copper cable
- 3.0 mm O.D. Round: flexible
- Low Power!
- Increased Air Flow
PARALIGHT Active Optical Cable Assemblies

- 2.5 to 10 Gbit/s per channel
- 0.8 Watt power dissipation
- BER $10^{-12}$
- For sequence length $2^7-1$
- Total Jitter 0.42 UI
Design and performance constraints
Interconnect density comparison

Density of copper interconnect

- Based on design rules for 10 Gb/s
- 1.5 mm horizontal spacing
- 0.5 mm vertical spacing

Density of optical interconnect

- Based on MTP standard
- 250 μm horizontal and vertical spacing
- 18 fold density increase
Optical layout advantages

**Splitters**
- Optical power splitters
- Branch number dependent on link budget

**Crossovers**
- Signal crossovers on one layer
- Different crossover angles possible
Polymer Multimode Waveguide Interconnects

- Straight waveguides – Optical InterLinks
- 90° Crossings – Dow Corning
- 90° Crossings – Heriot Watt University
- Waveguide cores – Exxelis
- 50° Crossings – Exxelis

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Fully Interconnected System Demonstrator

Fully connected waveguide layout using design rules

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The Shortest Waveguide Illuminated by Red Laser
Waveguide with 2 Crossings Connected 1\textsuperscript{st} to 3\textsuperscript{rd} Linecard Interconnect
Output Facet of the Waveguide Interconnection
Xyratex Electro-Optical Midplane
Optical backplane connection architecture

Orthogonal docking

- Lens Interface
- Backplane
- Connector housing
- Parallel optical transceiver
- Copper layers
- FR4 layers
- Optical layer

Optical Backplanes in Data Storage Applications

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Optical backplane connection architecture

Butt-coupled in-plane connection

VCSELs

PINs

Single waveguide illuminated
Parallel optical transceiver

- Mechanically flexible optical platform
- MT compatible optical interface
- Geometric microlens array
- Quad VCSEL driver and TIA/LA
- VCSEL / PIN arrays on pre-aligned frame
Active pluggable connector

Parallel optical transceiver

Connector module

Spring loaded platform

Microcontroller

Optical Backplanes in Data Storage Applications
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Two stage connection mechanism

First stage
- Peripheral card inserted into midplane

Second stage
- Optical platform pushed forward
- Butt-coupled in-plane interface
Connector engagement mechanism

Docked

Cam followers

Ramped plug

Cam track
Dual lens coupling interface

Free space coupling
- Optimised for loss minimisation
- Maximum beam expansion

Dual lens coupling solution
- Beam expansion at coupling interface
- Reduces susceptibility to contamination

VCSEL
\[ \lambda = 850\text{nm} \]
\[ \varnothing = 7\mu m \]
\[ \text{Div} = 25^\circ \]

PIN
\[ \lambda = 850\text{nm} \]
\[ \varnothing = 70\mu m \]

Interface loss: 0.72 dB

Interface loss: 1.11 dB

Optimised for loss minimisation
Maximum beam expansion
Optical polymer

- Low loss at 850 nm

Waveguide characteristics

- $n_{\text{core}} = 1.56$
- $n_{\text{cladding}} = 1.524$
- $\Delta n = 2.3\%$
- N.A. = 0.33

Core dimensions

- $\phi = 70 \mu m \times 70 \mu m$
Peripheral test cards

- Optical connector site
- C-PCI connector
- PCI bridge
- Array connector
- 8 x 8 crosspoint switch
- FPGA
- XFP front end
Demonstration platform

Compact PCI chassis

Electro-optical midplane

Pluggable optical connector

Peripheral test card

Single board computer
High speed data transmission measurements

- **1st test card**
  - 10 GbE LAN test data
  - Injected into front end

- **Electro-optical midplane**
  - Pluggable connectors
  - Polymer waveguides

- **Target test card**
  - Retrieved through front end
  - Signal integrity measured
High speed data transmission measurements

Test data captured on 8 waveguides
- Data rate: 10.3 Gb/s
- Typical Pk to Pk jitter: 26 ps

BERT on waveguides
- Measured on all waveguides
- BER less than $10^{-12}$ measured
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