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Bell Labs Innovations

LC Connector
A High Density Fiber Optic Network Solution

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Lucent Technologies,
Bell Laboratories

IEEE 802.3z Gigabit Ethernet
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LC Connector Outline

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- Design Background and Goals
- Product Family Overview
- Features
- Feature Advantages
- Adapters, Transceivers, Cordage
- Standards, Licensing and Availability
- Performance
- Summary & Conclusion

LC Connector Background

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- Bell Labs was challenged with developing a **next generation optical connection product family** that would meet the changing needs of **both the singlemode and multimode** markets
- MM and SM teams developed similar conclusions
- Developed design criteria based on market trends
  - Lower system cost
  - Smaller size
  - User friendliness
  - Excellent mechanical and optical performance

LC Connector Design Goals

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- Develop one connector/optical interface for **ALL** applications in the network
  - High volume = low cost
  - Fewer equipment designs
    - » lower cost
    - » less R&D expense for xcvr. manuf. and OEMs
  - Specialty connectors traditionally not successful
    - » high price
    - » low volume, not accepted by total market
- No Cost shifting to **ANY** network components!
- Develop a complete product family
- Broadly license for multiple sources

LC Connector Product Family

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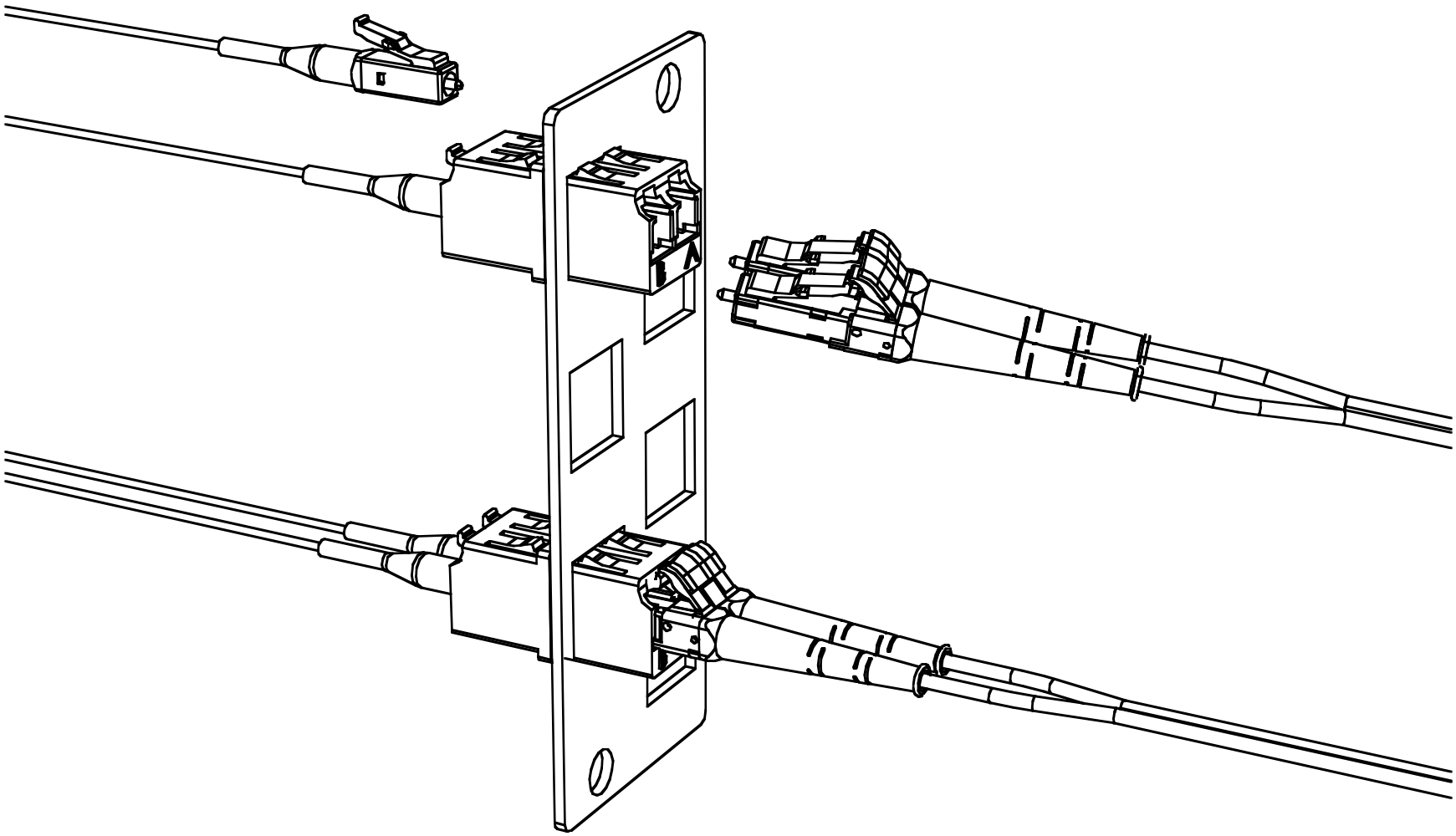

LC Product Family
Multimode and Singlemode

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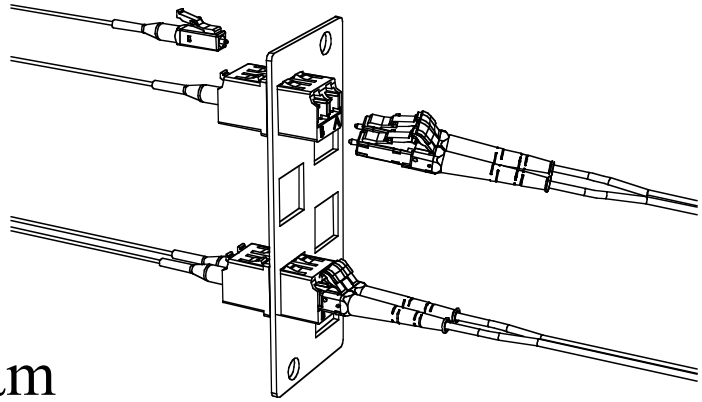

Initial Product Offering

- Patch Cords and pigtails
  - Duplex and simplex
  - MiniCord™ (1.6 mm) and 900 µm
  - Hybrid Patch Cords
- Field-mountable on buffered-fiber & cordage
- Duplex adapters
  - standard and reduced height
- Panels for outlets and cabinets
- Mounting Collar for RJ-45 cutout

LC Connector Features

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- RJ-45 Style
- Small Size
- Polarized
- Color Coded
- Pull-Proof
- Cable Compatible
- Excellent Performance
- High Reliability

LC Connector
Feature Advantages

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- RJ-45 Style
  - User friendly (intuitively obvious operation)
  - Familiarity of copper modular plugs
  - No tools
  - Easy insertion and extraction
  - Audible click assures full insertion
  - Low-cost plastic housing
  - Improved anti-snag latch

LC Connector
Latch Enhancements

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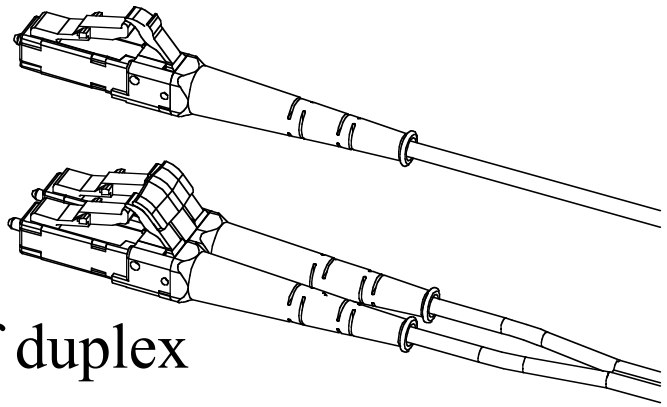
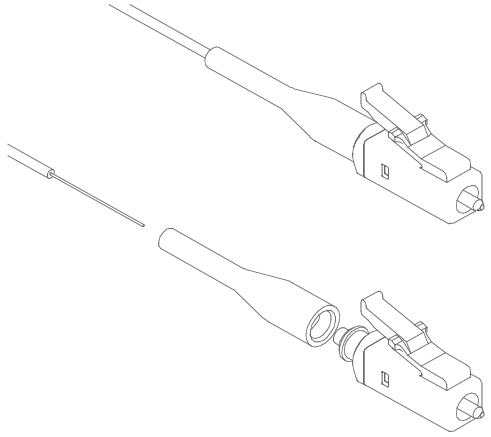


- Patch Cords
  - Anti-snag feature on latch
  - Easy to disengage simplex
  - Simultaneous disengagement of duplex
- Buffered Fiber Connector and Pigtail
  - Finger catch on latch
  - Extended latching beam
  - Easy to locate and disengage
- Robust Latch
  - Flex tested 7000 times



LC Connector
Feature Advantages

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- Small Size
  - Smaller than RJ-45
  - Half size of duplex SC
  - PCI mezzanine compliant for NICs
  - Lower system cost
    - » double density panels and hubs
    - » fewer panels and racks, less floor and closet space
    - » same interface for MM and SM
    - » designed for automated manufacturing
    - » alternate ferrule and sleeve materials
    - » no cost shift

LC Connector
Feature Advantages

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- Polarized
  - Obvious orientation to adapter
  - Installs in only one orientation
  - Maintains Tx/Rx directions
  - No keying
  - Repeatable performance
  - A / B polarity markings
  - Meets TIA 568-A and ISO 11801

LC Connector
Feature Advantages

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- Color Coded
  - Meets TIA 568-A and ISO 11801
    - » SM blue
    - » MM beige
  - Easily identifiable fiber type
- Pull-proof
  - Side and axial load tolerant
  - Eliminates accidental disconnections
  - Increases reliability

LC Connector
Feature Advantages

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- Cable Compatible
  - Works readily with installed base
    - » 900 µm buffered (indoor cable)
    - » 250 µm coated (ribbon, loose tube OSP)
    - » standard strength fiber
  - Special fiber or cable **not** required
  - Easy to mount
    - » buffered fiber or cordage
    - » familiar procedure
    - » less polishing
  - Lower cost
    - » no cost shifting

LC Connector
Feature Advantages

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- Excellent Performance
  - Meets industry opt., mech. and env. standards
    - » TIA 568-A
    - » ISO 11801
    - » Bellcore GR-326
  - Design guarantees end-face contact
    - » easily meets 20 / 26 dB return loss
  - Pull-proof

LC Connector
Feature Advantages

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- High Reliability
  - Proven technology
  - No inherent fiber bends
  - Durable materials
    - » 500 re-matings
    - » 7000 latch flexures
  - Easily cleaned
  - Low Risk means Lower Cost

LC Adapters
Features and Advantages

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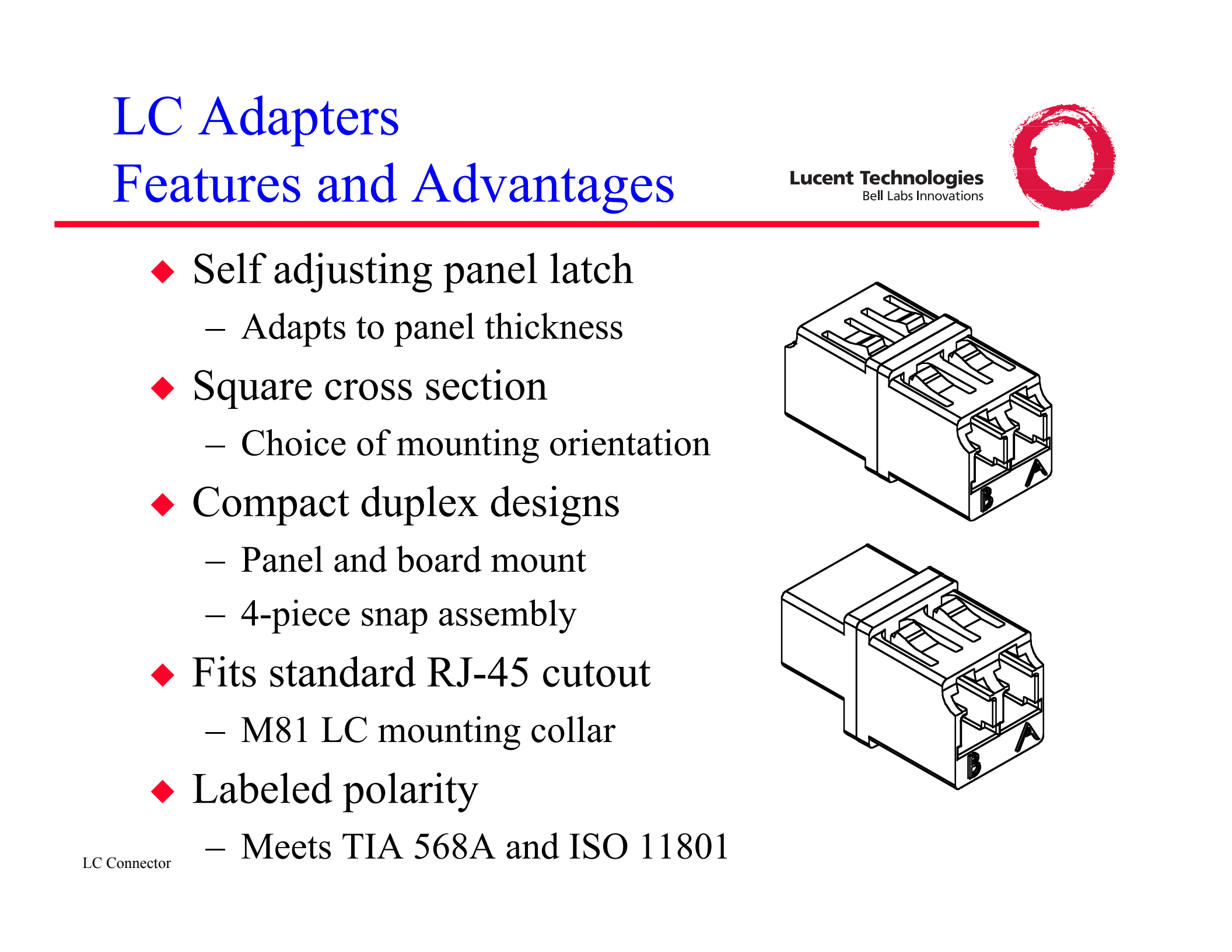

- Self adjusting panel latch
  - Adapts to panel thickness
- Square cross section
  - Choice of mounting orientation
- Compact duplex designs
  - Panel and board mount
  - 4-piece snap assembly
- Fits standard RJ-45 cutout
  - M81 LC mounting collar
- Labeled polarity
  - Meets TIA 568A and ISO 11801

LC Connector Transceiver Interface

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- Maximize hub density
  - Needs less panel space than UTP jack
- PCI mezzanine compliant
  - Compatible with PC NICs
- No cost shifting
  - Familiar, miniaturized design
- Low insertion and withdrawal force
- LC transceiver suppliers
  - Finisar
  - Working with others

LC Connector MiniCordage

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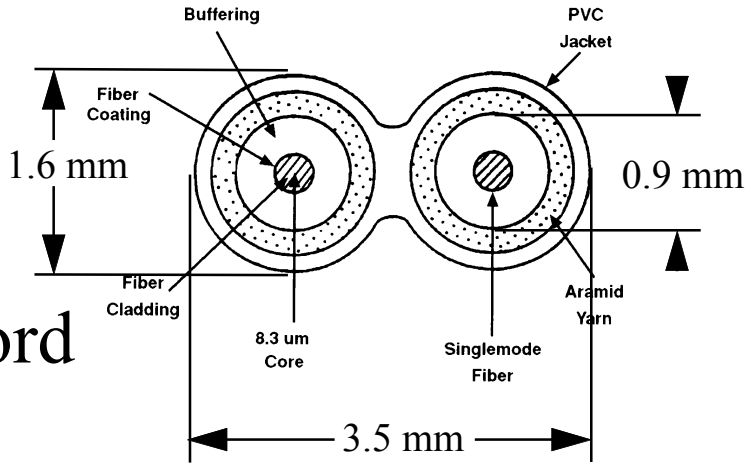
- Small diameter - 1.6 mm simplex
  - Alleviates trough congestion
  - Simplex, duplex zipcord, and quad
  - Duplex size 66% of 2.9 mm ribbon cord
- Excellent performance
  - Made for pull-proof connectors
  - Tight bend radius (1inch)
  - GR- 409 Bellcore compliant
- Lower cost than 3.0 mm zipcord

Duplex Minicord



LC Standards, Licensing and Availability

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- Standards
  - Actively working standards
    - » TIA FO6.3 FOCIS work item approved
    - » IEC 86B WG 6: submission approved by USTAG
- Broadly Licensing
  - Actively negotiating with several companies
- Availability
  - Limited production September 1996
  - Full Production March 1997
  - 3 beta sites in progress (> 10,000 connectors)

LC Performance

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- Optical
- Environmental
- Mechanical

Optical Performance
Multimode - Insertion Loss

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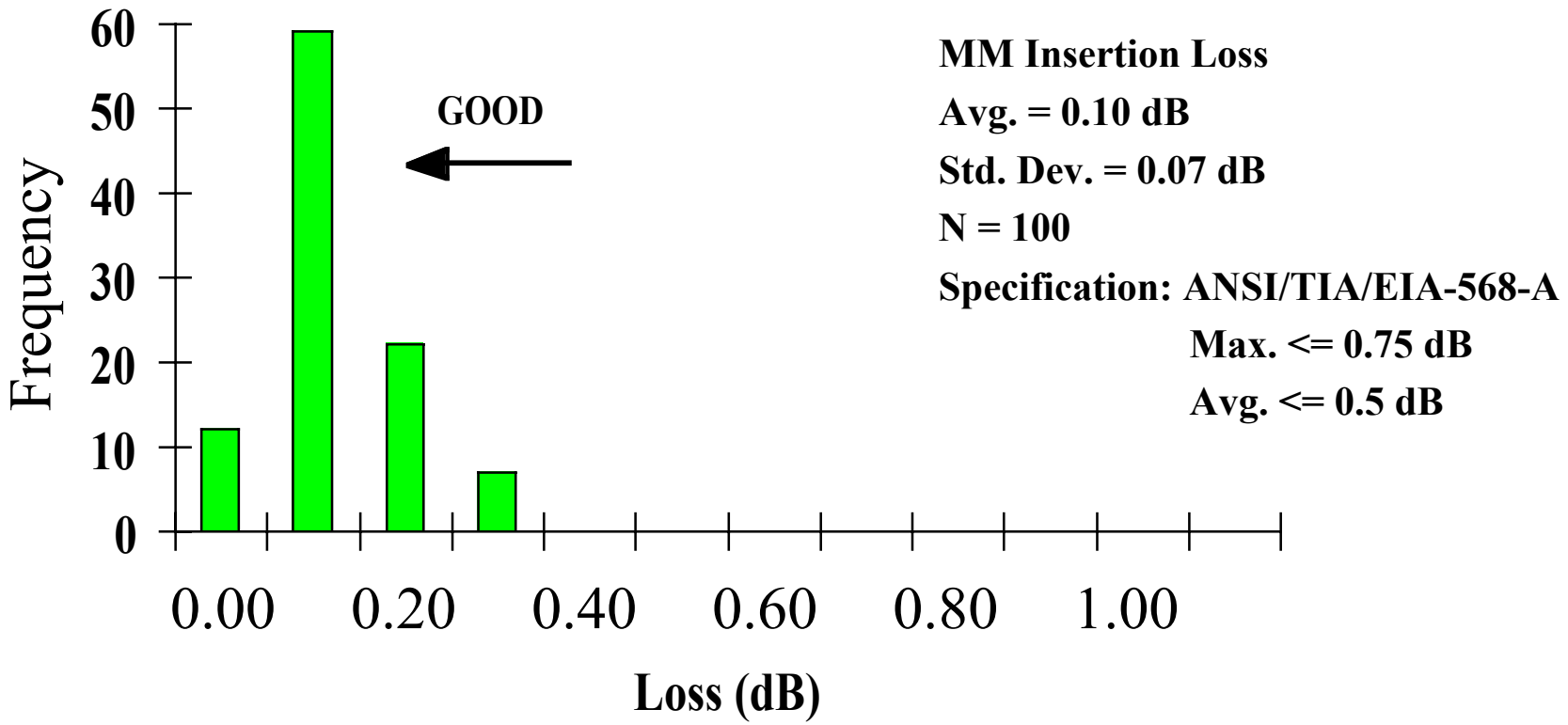

Optical Performance
Multimode - Return Loss

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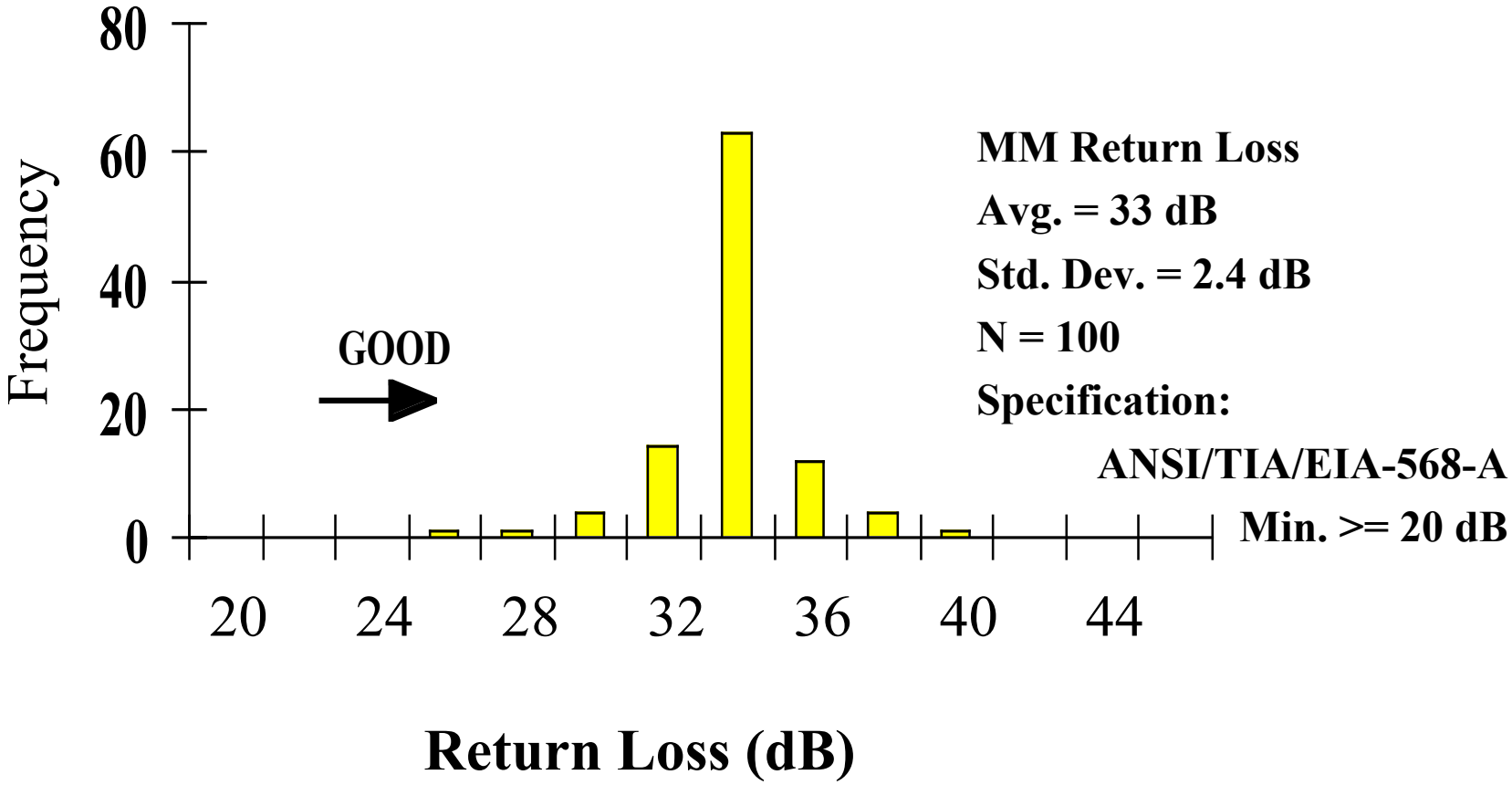

Optical Performance Singlemode

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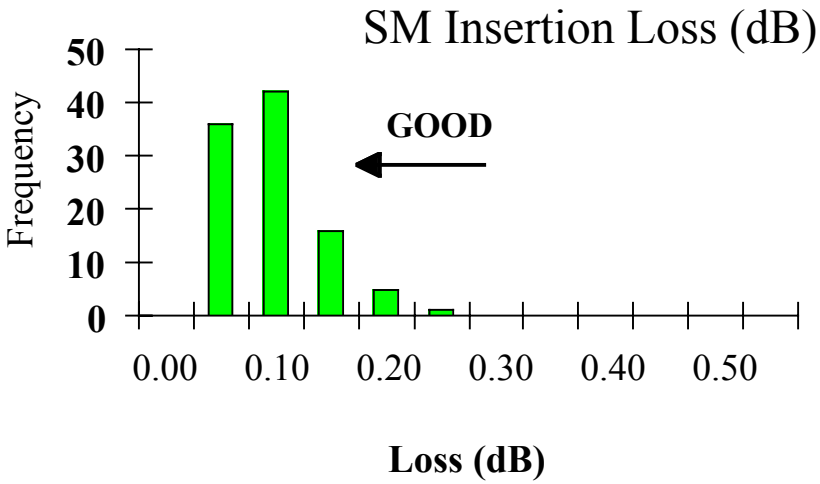
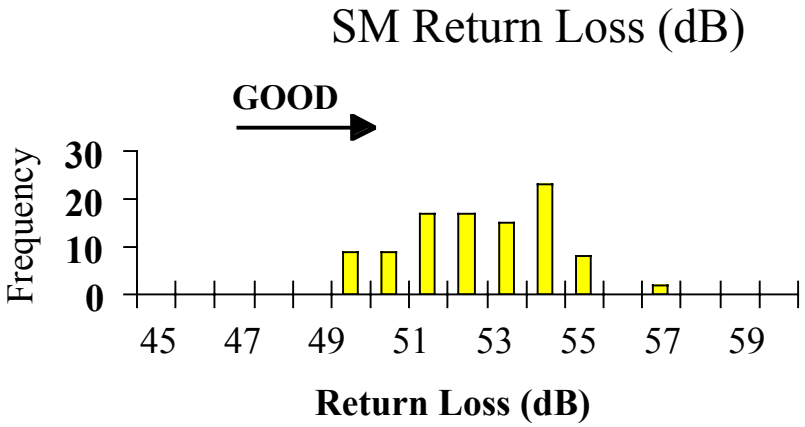


SM Loss
Avg. = 0.09 dB
Std. Dev. = 0.05 dB
N = 100
Specification :
ANSI/TIA/EIA-568-A
Max. <= 0.75 dB
Avg. <= 0.5 dB



SM Return Loss
Avg. = 53 dB
Std. Dev. = 1.9 dB
N = 100
Specification :
ANSI/TIA/EIA-568-A
Min. >= 26 dB

Environmental Performance Multimode

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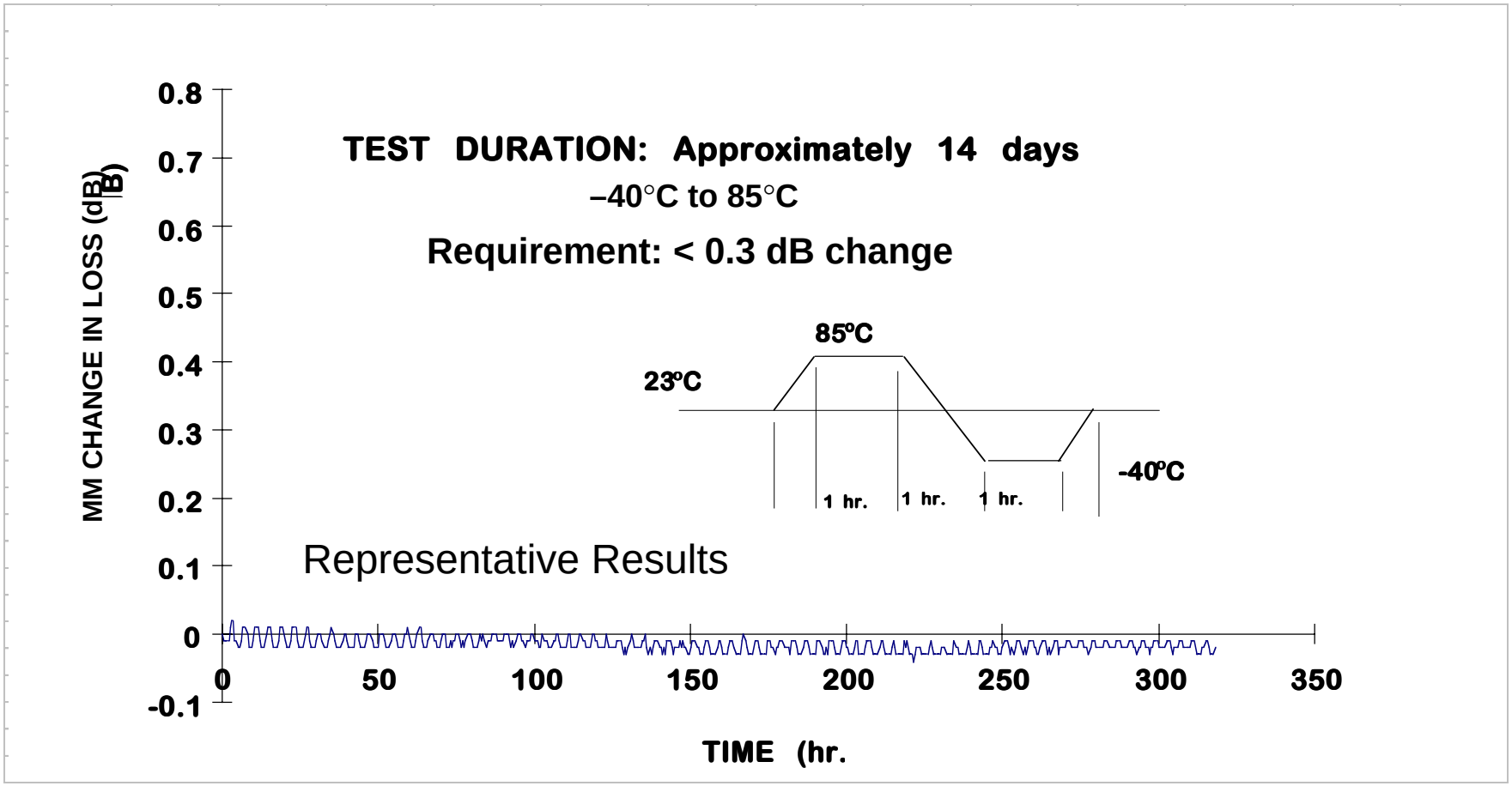

Mechanical Performance
Mating Durability

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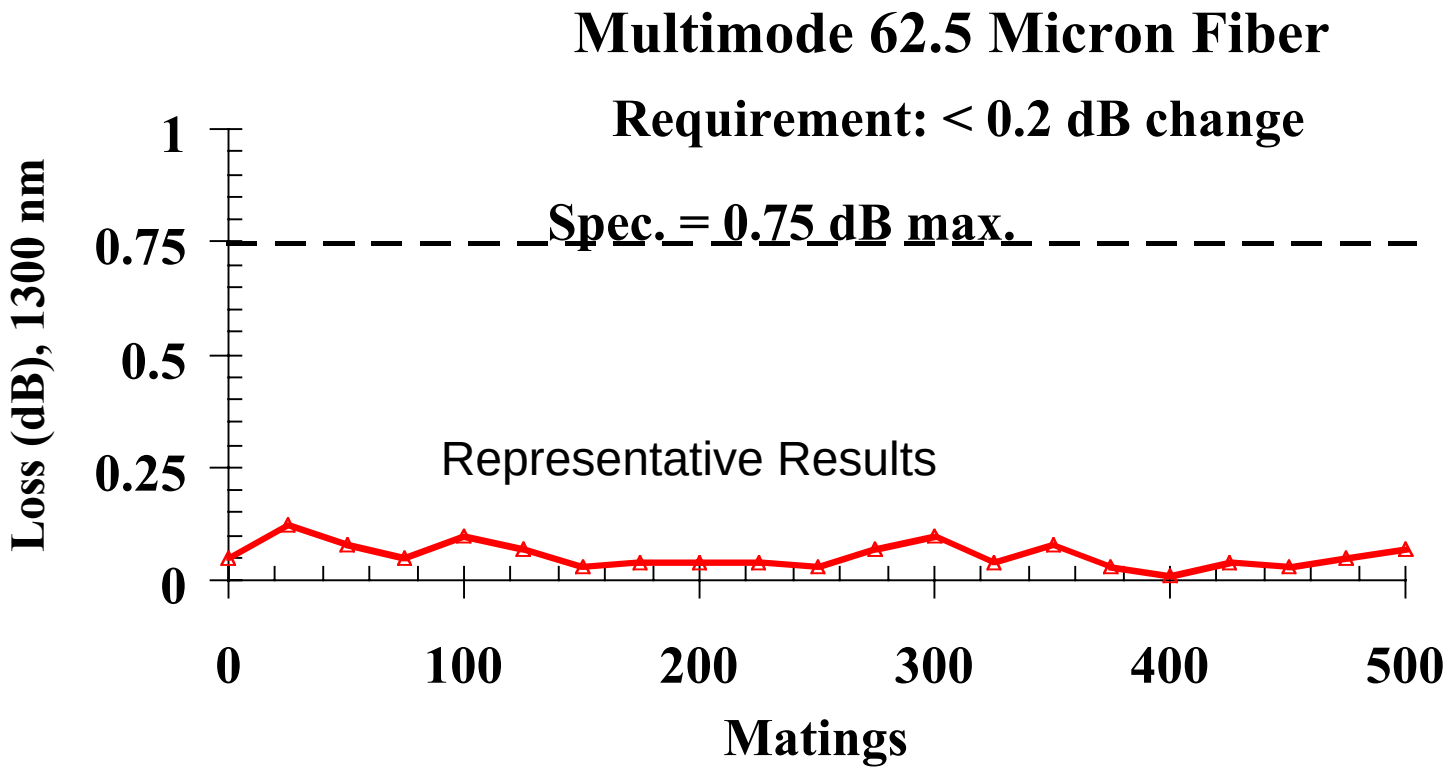

Mechanical Performance
Tensile Load - Singlemode

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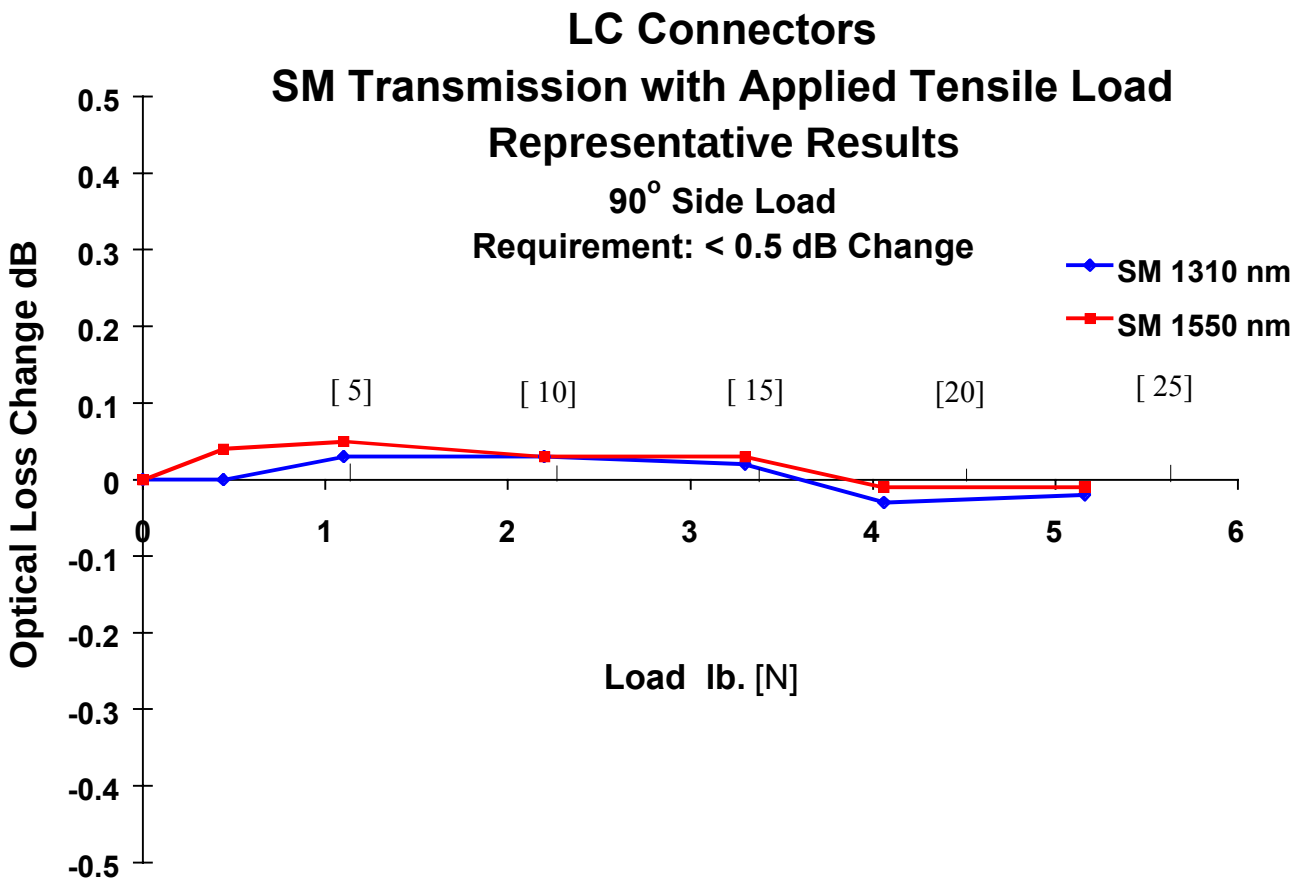

Performance Specification Multimode

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- Insertion Loss
  - 0.10 dB average, 0.10 dB standard deviation
- Return Loss
  - 33 dB average
- Temperature Cycling
  - -40 to +85 C; loss change < 0.30 dB
- Mating Durability
  - 500 matings; loss change < 0.2 dB
- Tensile Loading
  - 0 deg, 10 lbs < 0.2 dB
  - 90 deg, 5 lbs < 0.2 dB

Performance Specification Singlemode

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- Insertion Loss
  - 0.10 dB average, 0.07 dB standard deviation
- Return Loss
  - 50 dB minimum
- Temperature Cycling
  - -40 to +85 C; loss change < 0.30 dB
- Mating Durability
  - 500 matings; loss change < 0.2 dB
- Tensile Loading
  - 0 deg, 10 lbs < 0.2 dB
  - 90 deg, 5 lbs < 0.2 dB

LC Connector Summary

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- Lower system cost
- RJ-45 housing
  - The most user friendly
  - 1/2 size of duplex MM SC
- Proven, reliable technology
- Compatible with embedded fiber base
- Will broadly license
- Actively working standards

LC Connector Conclusion

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- Bell Labs invented the ST connector
  - Standard for 10BASE-F
  - Grandfathered in TIA 568-A and ISO 11801
  - Most popular optical connector in the world
- Bell Labs also invented the modular plug
  - Most prevalent copper connector worldwide
- The LC combines the best of both
  - Proven technology of the ST
  - Miniaturized and embodied in a modular plug
- Examine all facts from a total system perspective
  - The LC is the best choice