Are You Ready to Deal With the Rapidly Changing Demands of Today’s Modern Data Center?

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**Doug Baker** – 10+ years of Product Management experience in passive infrastructure and developing structured cabling solutions

**Lucas Mays** – experienced Application and R&D Engineer solving the challenges of field fusion splicing and network installation

**Rob Gilberti** – 25+ years of experience within cable manufacturing, connectivity and hardware, laser manufacturing and Test and Inspection equipment.
4G to 5G:
- Latency: 10 ms vs. < 1 ms
- Data traffic: 7.2 Exabytes/month vs. 50 Exabytes/month (2021)
- Peak data rates: 1 Gb/s vs. 20 Gb/s
- Available spectrum: 3 GHz vs. 30 GHz
- Connection density: 100 thousand connections/Km² vs. 1 million connections/Km²
Central Cloud Data Center

Network Edge Data Center

Customer & Application Edge

Latency > 100ms ~ 20ms < 10ms

Backhaul to the Internet

2019 BICSI FALL Conference & Exhibition
At the Heart of the Smart City

Energy Saving

Easy Parking Management

Central Control / Monitoring

Access Control & Electronic Data of Attendance

Reduced Manpower & Human error

Continuous Surveillance

Human Safety

Reduced Panic During Fire

HVAC Monitoring & Control
High Density Cabling
Today’s challenges – Passive Cabling

- Requirements for very high density cross-connects between facilities
  - Applications for up to 6,912ct
- Requirements for high density passive in-building cross-connects
  - Configurable, Flexible, Easy to install, handle
- Low-Loss
- Ease of use, maintenance
  - Ribbon solutions reduce handling
  - Fewer splices, more efficient maintenance
- Access
- Global consistency in solutions offerings
Challenge: High-Density Cross Connects

• Typically Outside-Plant (OSP) cable due to distances and conditions on-campus or between Installations.
  • Maximize Connections while minimizing infrastructure
    • Pathways, Connectivity, Installation expense

• Innovative new cable options exist that incorporate the following features:
  • Latest generation ribbons that promote Mass Fusion splicing
  • Dry-Core or Gel-Free constructions
  • Smaller Cable Diameters
  • Ease of use
    • Handling
    • Cable entry
    • Organization
Leading Cable Characteristics

Latest Generation Ribbon

- Promotes use as Ribbon or Loose Fiber
  - Enables Mass Fusion splicing, or Individual splice connections
  - Maximizes use of space in cable core
- Clear Organization

Smallest Diameters

- Maximize pathway utilization
  - High Fiber Counts
Latest Generation Ribbon Cable Size Advantage over Traditional OSP Cable Designs

<table>
<thead>
<tr>
<th></th>
<th>144F</th>
<th>288F</th>
<th>432F</th>
<th>864F</th>
<th>1728F</th>
<th>3456F</th>
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<tr>
<td><strong>Loose Tube Cable</strong></td>
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<td></td>
<td>16.0 mm</td>
<td>18.9 mm</td>
<td>21.0 mm</td>
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<tr>
<td><strong>Ribbon Loose Tube Cable</strong></td>
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<tr>
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<td>13.9 mm</td>
<td>19.8 mm</td>
<td>19.8 mm</td>
<td>25.1 mm</td>
<td>35.4 mm</td>
<td>—</td>
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<td><strong>Flexible Ribbon Cable Example</strong></td>
<td></td>
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<tr>
<td></td>
<td>10.5 mm</td>
<td>12.0 mm</td>
<td>13.5 mm</td>
<td>17.5 mm</td>
<td>23.0 mm</td>
<td>30.0 mm</td>
</tr>
</tbody>
</table>
Pathway use example

• Latest Generation Ribbon vs Conventional Loose-tube
  • Illustrates the impact of the evolution in design
  • 3 – Way, 1.25/1.50 in Microduct system measuring 3.0 in Diameter

• 288ct Traditional Loose-Tube

• 864ct Ribbon
  • Same density in one Microduct accomplished with 3 x 288ct in Traditional!
Challenge: In-Building Optical Cable

- Inside-Plant cabling
  - Maximize Connections while minimizing infrastructure
    - Pathways, Connectivity, Minimizing Installation expense

- Cabling options exist that incorporate the following features:
  - Latest Generation ribbons that promote Mass Fusion splicing
  - Structures that promote ease of use, installation
  - Smaller Cable Diameters
  - Maximum configurability
    - Bulk – can be managed on-site
    - Pre-terminated
      - Single-end or fully pre-terminated
Leading in-building cable attributes

High count backbone cabling can be installed via Splice or high-density connections

Match Cabling structure to connectivity scheme
  • Available up to 1728ct
  • 8, 12, 16 or 24 count sub-cable build-out

Latest Generation Ribbon (base building block)
  • Use as Ribbon or Loose Fiber
    • Enables Mass Fusion splicing, or Individual splice connections
    • Maximizes use of space in cable core
  • Clear Organization
Another Option: Jetted MicroCable

Alternative to Traditional Sub-Cable style
Characterized by:

- Individual pathways
  - Enhances Security
  - Minimizes post-install access requirements
  - Configure to specific needs
  - Easy moves, adds and changes
- Air-assist installation
- Ribbon construction
  - Mass Fusion splicing
Next evolution in Density/Pathway utilization

200um Single-mode Fiber (SMF)
- ITU G.652, ITU G.657 grade, backwards compatible
  - Single Fiber and Flexible Ribbon options

- Core, Cladding dimensions match current 250um infrastructure
  - Strip, Clean, Cleave process are similar to current best-practice

- Further reduces the impact of the passive cabling infrastructure
  - 35% reduction in fiber cross-section impacts all elements of cable design
  - Smaller cable diameters – higher density in existing or future constructions
  - Lower weight, smaller bend radii

Courtesy: The Light Brigade
Next evolution in Density/Pathway utilization

• Examples of cross-sectional impact (Inside-Plant cable)

Current 72f – 8.2mm
200um 72f – 7.0mm

• Important Points to consider with 200um
  
  • When deploying Ribbon..
    • Look/Specify solutions that are backwards compatible
    • 250um Pitch to match standard solutions already deployed
      • Standard work processes apply
      • Little re-training required
In Summary

• Very high density optical interconnects are now possible and commonly deployed

• Technologies have evolved to support efficient, cost-effective installation techniques
  • Enhanced Mass Fusion splicing
  • Cable handling and maintenance
  • Customizable solutions (build in place)

• Structured cabling impact will continue to be reduced with deployment of 200um Single-mode solutions in Next-Gen solutions
The Fiber Management Challenge
Challenge: Managing increasing Densities and potential for Network Migration

- Increasing fiber counts in Backbone and Zone cabling

- Depending on protocol, channel counts are increasing leading to increased optical fiber densities

- Migration to increased transmission rates drives configuration changes of structured cabling to meet performance requirements
  - Especially when deploying Multimode fiber (MMF)
Challenge: High Density Connectivity

Entry and Backbone Cabling – How to deal with all the inbound fiber?

18,432F Splice Cabinet

Dedicated Patch and Splice

6,912ct Wall/Rack Mount Splice

Terminated Panels – Splice at Entry Point
Example application

ENTRY

Wall-mount or rack-mount application

1,728 ct OSP Cable
  • Ribbon construction

6 x 288 ct In-Building trunk cables

144 ct Ribbon Splice Trays

2RU 288 ct Panels
  • Can be factory built, field spliced or built on-site
Challenge: High Density Connectivity

Backbone and Zone Cabling – How to deal with all the fiber?

- Dedicated Patch and Splice
- Pre-terminated Cabling
- Build in-place MPO Trunks
- Bulk Cable
- Field Installed MPO
Challenges impacting Passive Connectivity

• Protect investments in infrastructure against Future needs
  • Base 8, Base 12 or Base 24 Configurations
    • Can my infrastructure be configured to account for changes?
  • Maximize use of floor/rack space while enhancing ease of maintenance
  • Select MMF or SMF – this impacts structured cabling selection

• Work to minimize network loss between interconnections to maximize performance
  • Select Low-Loss connectors
  • Consider Splice vs Connected links
Multimode vs single-mode fiber cabling is dependent on the type of Data Center, link lengths, and expected bit rates

**Enterprise**
- 1GbE to 10GbE to 40GbE
- Up to 150 meters
- Multimode meets most needs
- Parallel optics to meet increased bit rates
  - MPO connectors
- Shortwave wavelength division multiplexing (SWDM) with OM5 presents new growth path

**Hyperscale**
- 25GbE to 100GbE and beyond
- 500 meters to 2 km
- Single-mode meets the current needs, and can meet future requirements
- Increase serial speed to 100GbE+ and parallel speed to 1TbE
  - MPO
- Course and Dense Wavelength Division Multiplexing (CWDM and DWDM)
  - Duplex LCs
Standards Based Data Rate Migration Path to 400GbE on MMF

<table>
<thead>
<tr>
<th>Multimode Fiber Type</th>
<th>10GbE</th>
<th>40GbE</th>
<th>100GbE</th>
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<tr>
<td>OM1</td>
<td>33 m</td>
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<td>OM2</td>
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<td></td>
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</tr>
<tr>
<td>OM5 **</td>
<td>400 m</td>
<td>150 m</td>
<td>150 m</td>
<td></td>
</tr>
</tbody>
</table>

* Future
** OM5 WBMMF (wideband multimode fiber) ANSI/TIA-492AAAE
Multimode Migration Path in Data Centers
40 GbE to 100 GbE (using 25 GbE Laneways)

- 100 GbE (4 x 25 GbE parallel optics)
  - OM3 VCSEL  70 meters  8 Fibers
  - OM4 VCSEL  100 meters  8 Fibers

Replace transceivers, but may not need to replace cable assemblies
Multimode Migration Path in Data Centers
40 GbE to 100 GbE (using 10 GbE Laneways)

- 100 GbE (10 x 10 GbE parallel optics) – 1st generation
  - OM3 VCSEL 100 meters 20 Fibers
  - OM4 VCSEL 150 meters 20 Fibers

Replace transceivers and cable assemblies

24 Fiber MPO

2 x 12 Fiber MPO
Leading Panel Technologies to ease migration

- Built around Cassette/Module framework
  - Base 8, Base 12 or Base 24 Elements

- Supports migration when changes are required
  - Drive to utilize existing cabling infrastructure
  - Interchangeable components

- Maximize flexibility within the Panel system

- Ease of access, Front or Rear of panel
Leading Backbone and Patch Cord Attributes

Trunks

- Small diameter constructions supporting Base 8, 12 or 24 frameworks
  - Commonly referenced as Micro Cable
  - Ribbon and Flexible ribbon may be selection of choice
- Engineered to support Cassette/Module conversion
- Terminated with Gender and Polarity reversible MPO/MTP® connectors

Patch Cord

- Small diameter construction
- Terminated with Reversible Connectors
- Enhanced handling with push/pull features
What’s Next – Enhances need for modularity

• Increasing panel density
  • Small Form factor connectors (2x, 4x LC Densities)
    • Supports growth of transmission lane requirements
    • Reduces physical impact

• Growth of Multiplexing in the Data Center to achieve targeted Bit rates 400Gbe or Greater
  • Both MMF (OM5) and SMF
Low Loss, Rapid Splicing – What Modern Data Centers Demand

Lucas Mays
Rapid Splicing = Mass Fusion Splicing

• Mass Fusion Splicing
  • Any time you are preparing and splicing multiple fibers at a single time - range is from 2 to 12

• Most commonly used with 12 fiber ribbons
Rapid Splicing = Mass Fusion Splicing

• Labor and time savings from Mass Fusion splicing are **HUGE**
  • Recent internal study estimates 87% reduction in splice time
• As fiber counts increase, single fiber splicing becomes unrealistic

• Bottom Line: Reduce labor cost and turn-up time with Mass Fusion
Mass Fusion is Low Loss Capable

• Modern day fiber is friendly to low loss even when Mass Fusion spliced

<table>
<thead>
<tr>
<th>Fiber Combination</th>
<th>Average Splice Loss (dB)</th>
<th>Standard Deviation</th>
<th>Maximum Splice Loss (dB)</th>
<th>Minimum Splice Loss (dB)</th>
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<tbody>
<tr>
<td>G.657 #1 to G.657 #2</td>
<td>0.03</td>
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<td>0.07</td>
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<td>0.02</td>
<td>0.017</td>
<td>0.08</td>
<td>0.00</td>
</tr>
</tbody>
</table>

• However, achieving low loss splices hinges on a few key subjects

Reference:
Low Loss – What it Takes

• A mass fusion splice is not a trivial process
  • Maintaining consistency over thousands of arcs even less so

• Reputable splicer is recommended as a baseline for continued quality ribbon splices

• Arc consistency is under your control
  • If not maintained, splice quality suffers
  • Adhere to manufacturer’s guidance on electrode replacements and arc calibrations
Low Loss – What it Takes

• Three major factors affect low loss capability – a.k.a. splice quality
  1) Fiber quality – as it relates to core/cladding concentricity
     a. Your cable supplier will help here
  2) Arc consistency
  3) Ribbon preparation

• If you can choose your fiber – choose high quality glass
  • It has implications beyond splicing

• If not, ribbon prep and arc consistency are the only factors you control
Low Loss – What it Takes

• Ribbon preparation requires *consistent precision* for quality splices
  • I.e. - continual high quality ribbon stripping, cleaning, and cleaving
  • This becomes increasingly challenging when splicing high fiber counts

• #1 – Follow manufacturer’s operation instructions

• Major pain points that hinder consistent precision
  1) Cleanliness
  2) Equipment ergonomics
  3) Cleaver blade management
Pain (Points) Management – Cleanliness

• Mass Fusion Cleanliness – In General
  • Higher importance
  • Requires more diligence
  • Different techniques and processes

• Thermal Stripper cleanliness management
  • Particularly problematic with collapsible ribbons
  • Use a toothbrush to remove broken down coating
Pain (Points) Management – Cleanliness

• Splicer v-grooves require periodic cleaning at minimum
  • Or when large pre-splice offsets appear and re-prepping the ribbon does not resolve
  • Special kits exists for Mass Fusion v-groove cleaning
  • Absolutely a requirement for quality work
• Fiber holders and cleaver clamp pads also need to be cleaned occasionally
  • Especially if proper fiber cleaning is not observed
  • Use lint-free cotton swab and alcohol to clean
Pain (Points) Management – Ergonomics

• Ribbon fiber preparation consists of several manual processes
• After 288 or more cycles, these repeated motions can wear down operator hands
  • Highest contributors are thermal stripping and cleaning
• Pay attention to and ask about ribbon prep tool ergonomics – some are more friendly than others
Pain (Points) Management – Cleaver Blade

- Largely underrated as a key factor in consistent low loss splices
- Some inductive reasoning to justify the importance
  - Good blade positions = good cleaves
  - Worn blade positions = bad cleaves
  - Good cleaves = good splices and bad cleaves = bad splices
  - Therefore, good positions = good splices and bad positions = bad splices
- Track your blade positions to maintain using a good one
  - You will better maintain quality splices and save time from rework
Pain (Points) Management – Cleaver Blade

• How do I know when a blade position is worn?
Pain (Points) Management – Cleaver Blade

- Difficult to manage with traditional cleavers and splicers
- Varying solutions exist to manage blade positions – below shows an automated example
In Summary

- Fast-paced, low loss installs to meet today’s Data Center demands requires
  1) Mass Fusion splicing instead of single fiber splicing
  2) Low loss splices to meet loss budget requirements
     a. Follow manufacturer’s operation instructions of your equipment
     b. Choose high quality fiber if possible
     c. Start with quality splicer and maintain arc calibrations
     d. Consistent precision in ribbon preparation
        i. Address major pain points
Clean for Success
Presentation Outline

• Fiber optic connector inspection – why?
• Effects of Connector Contamination
• Standards for auto-analysis of endfaces
• Cleaning/Inspection Best Practices
• Multi-fiber/MPO Considerations
• Inspection image processing challenges
• New connectors for new applications
#1 Problem: Dirty / Damaged Connectors

- “98% of installers and 80% of network owners reported that issues with connector contamination were the greatest cause of network failure” – NTT Advanced Technology
Fiber Optic Connector Inspection – Why? (1 of 4)

Optical network operational realities are harsh
- Contaminated or damaged optical connectors can bring down networks

- PAM4 modulation for 100G single lambda transport has reduced optical link budgets, making sensitivity to connector attenuation and reflection increasingly pronounced – “You may have gotten away with it until now”

- Today’s network operators must engage in 100% connector endface inspection to avoid costly network downtime
Fiber Optic Connector Inspection – Why? (2 of 4)

Evolution from single fiber cabling to multi-fiber cabling

• Appetite for ever higher broadband speeds
  • Multi-wavelength multiplexing per fiber
  • Higher frequency (lower wavelength) carriers
  • Parallel optics using multiple lanes of light

• Parallel Optics has driven the popularity of multi-fiber connectors, primarily MPO/MTP® variants
  • The worldwide installed base of MPO type connectors is more than 20M endpoints, with more than 4M endpoints to be commissioned in 2019 (conservative estimate)
Fiber Optic Connector Inspection – Why? (3 of 4)

• The business need for fast optical connector inspection
  • The revenue asset value of a 400G link is about $1M per year
    • 400 customers at 1 Gbps at approximately $100 per month or so with 2:1 oversubscription)

• As many as 80% of network failures are related to connector failures
  • often migrating dirt and other debris driven by aggressive forced air cooling systems

• The average cost of a Data Center outage is about $740K (Ponemon Institute / Emerson Network Power, Aug 2016)
Fiber Optic Connector Inspection – Why? (4 of 4)

Workforce changes, OPEX reduction, and the need for simple test instruments

• Increasingly, network turn-up and maintenance tasks are outsourced to inexperienced technicians, many with limited fiber handling skills

• Corporate senior managers demand their teams constantly find ways to reduce operating expense

• Drives requirement that network test and inspection tools are simple to learn and use with easy reporting of results
  • A prevailing attitude in the gig economy - “trust but verify”

Fast endface inspection tools are essential to help address these rising cost trends
What Really Happens?

• Dust and dirt can literally block the light

• Dirt and oils can cause light to refract and be lost at the connection

• Particles can prevent proper mating of connectors

• Dirt can damage connector end face when mating and cause permanent damage – cleaning will no longer help
Contaminants and the Connector

- 25 Microns
- 10 Microns
- 5 - 10 Microns
- 1 - 5 Microns
- 0.3 - 1 Microns

- Average Human Hair
- Lint, Particles Visible to the Naked Eye
- Heavy Dust, Lint, Fertilizer, Pollen
- Average Dust, Plant Spores, Mold
- Bacteria, Light Dust, Animal Dander
- Bacteria, Tobacco and Cooking Smoke, Metallic Fumes
Importance of Cleaning & Inspection

Dust/dirt residue transfer

- A connection is made of 2 connectors....
- They should both be inspected and cleaned if needs be.
What is Clean?

- IEC Standard
  Definition IEC 61300-3-35:2015
Standards for Auto-Analysis of Endfaces

International standards for auto-analysis

• IEC 61300-3-35 (2015) is the most commonly used international standard for pass/fail auto-analysis

• Defines two zones (core and cladding) to analyze for scratches and debris

• Pass/fail thresholds for both scratches/defects are established by count and by size

• This international standard is currently in the process of Edition 3 revision; a new revision is expected later this year or early 2020, with MPO/MTP inspection optimizations
Cleaning & Inspection Best Practice

START → INSPECT ENDFACE

ENDFACE CLEAN?

PASS → PLUG INTO CLEAN MATING CONNECTOR

FAIL → DRY CLEAN

PASS → INSPECT ENDFACE

ENDFACE CLEAN?

PASS → PLUG INTO CLEAN MATING CONNECTOR

FAIL → FAIL

FAIL → WET / DRY CLEAN

FAIL → FAIL

PASS → INSPECT ENDFACE

ENDFACE CLEAN?

PASS → PLUG INTO CLEAN MATING CONNECTOR

FAIL → FAIL

“Inspect Before You Clean”
IBYC

FOCIS Flex
FOCIS WiFi PRO
Multi-Fiber MPO
Probe Adapter Tips

One-Click MPO
NEOCLEAN-M
CLETOP-S8
OPTIPOP-R3

FCC2
FiberWipes
CleanWipes
CCT Tips
CLETOP Sticks
Step 1 - Inspect...

- You need to inspect **all** end faces in the connector
  - Inspect the entire connector to determine need for cleaning
  - Inspecting first verifies pre-connectorized products have been supplied in good condition
  - Just because a connector comes from the factory with a protective cap does not ensure it is clean
Step 2 - Clean...

- You need to be able to clean all of the end faces quickly and efficiently
  - There are cleaners available today specifically designed for multi-fiber connectors
  - Dry cleaning is quite effective, but is not perfect
Step 3 – Inspect (again)

• After cleaning you need to inspect all end faces in the connector again
  • If not clean... repeat the process and inspect again
  • Many customers now require proof of inspection to certify installations
  • Saves time and money in the long run

• Once Cleaned and verified – safe to connect
Clean connectors matter!

Dirty connectors = high insertion loss and high reflectance

Clean connectors = low insertion loss and low reflectance
Multi-Fiber Connectors - MPO

- The problem is multiplied
- More fibers in same space
Inspecting Multi-Fiber Connectors

• For multi-fiber connectors the criteria applies to all fibers in the array.

• It is especially important to clean loose contaminants beyond the contact point (Holes/Pins)
  • Debris can migrate and the close spacing of the fibers increases the chances of contamination causing issues
Algorithmic Auto-Analysis of Endfaces

Algorithmic auto-analysis in fiber optic connector inspection workflows

• Handheld wireless microscopes use real-time image processing to automatically analyze endface surface conditions

• Today’s inspection probes leverage the semiconductor sensors, microprocessors and memories found in modern smartphones

• Current generation fast MPO inspection probes can evaluate IEC pass/fail for each fiber in about 1 second (12 fiber MPO in about 10 seconds)

• This represents a true breakthrough as compared to older manual mechanical scanning methods (typically take about 60 seconds per fiber to position and run pass/fail analysis)
Inspection Image Processing Challenges

- Large number of variables to achieve consistent or repeatable auto-analysis connector inspection results
- MPO/MTP endface surface textures and colors vary widely from connector vendor to connector vendor
- Depending on the polish of the connector (flat UPC or 8 degree angled APC), the LED illumination level on the endface can vary dramatically
- Alignment sleeves (sometimes called bulkhead adapters) are precision manufactured but have tolerance limits
- Adapter tips used on the probes also have mechanical tolerance limits, which stack up with the alignment sleeve and the connector-under-test (patch cord or bulkhead) tolerances
- These physical realities limit the precision to which a real-time and low-cost microscope can make consistent and repeatable pass/fail judgments
New Connectors for New Applications

- Relentless demand for higher bandwidth drives to maximize switch faceplate density – typically limited by power and thermal management, and optical connector form factor issues.

- Serial optics based 100G transceiver MSAs utilized duplex LC connectors – but 6.25 mm ferrule pitch does not meet next generation Ethernet switch needs.
3.1 mm Ferrule Pitch Duplex Connectors

- Senko and US Conec have introduced new 1.25 mm ferrule duplex (and quadruplex, octaplex) connectors with tighter mechanical dimensions – **3.1 mm ferrule pitch**

Eight 1.25 mm ferrules fit in one QSFP-DD transceiver faceplate = duplex 4x 100G single $\lambda = 400G$
Next Gen Connector Support

Mechanical Push Type Connector Cleaner
For CS, SN, MDC Patch Cord endface cleaning

Typical Wireless Multi-Fiber Inspection Scope

APC and UPC 1.25mm Adapter Tips
For CS, SN, and MDC Patch Cords

Typical Wireless Single Fiber Inspection Scope
Wrap Up
Data is the life blood of our modern world

Connected by a vast infrastructure – wired and wireless – to enable transitional and monumental opportunities

The Modern Data Centers stands at the heart of this emerging reality....

The Data Singularity
Today’s Modern Data Center

• High Density Optical Cable stands as the foundation to today’s drive for more data
• Success requires interconnect management solutions that bring Order to Chaos
• Achieving low-loss interconnection is critical to meet the data rates required