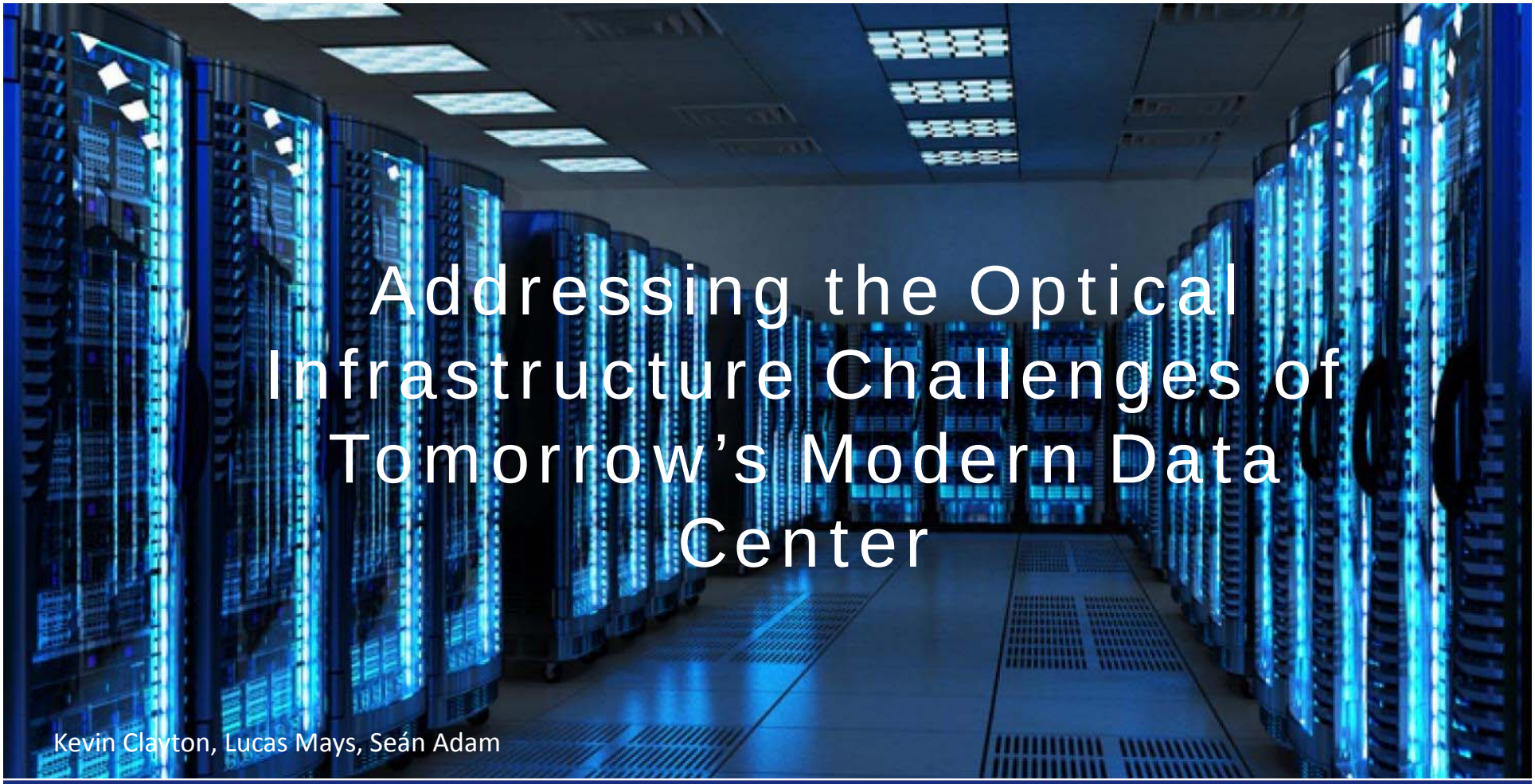


Addressing the Optical Infrastructure Challenges of Tomorrow's Modern Data Center

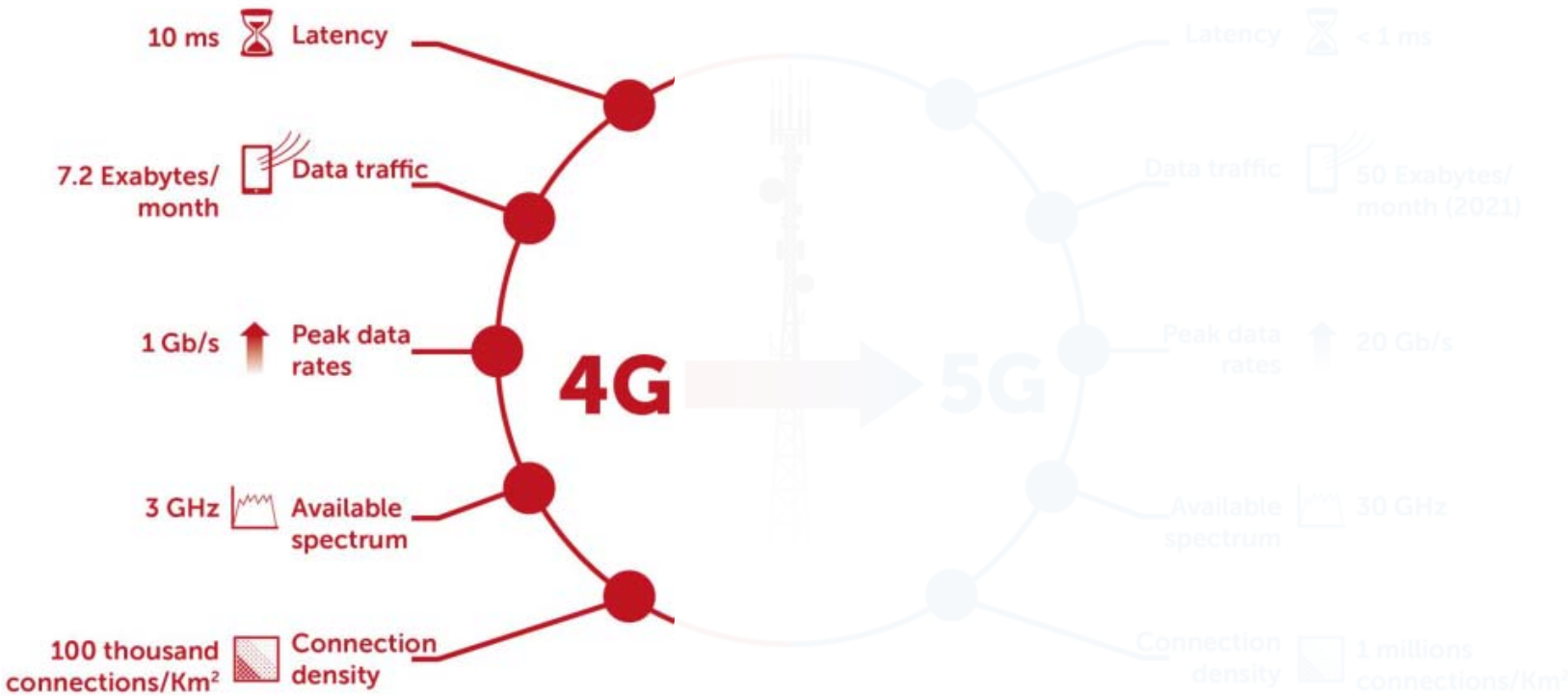
Kevin Clayton, Lucas Mays, Seán Adam

Kevin Clayton –20+ years of broad experience in the design and deployment of infrastructure hardware for the global telecommunications industry. Kevin is a certified Fiber-to-the-Home Professional (CFHP).

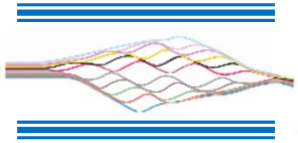
Lucas Mays – experienced Application and R&D Engineer solving the challenges of field fusion splicing and network installation

Seán Adam – 20+ years of R&D and Product Development in the Semiconductor and Telecom industry with a focus on system-based solutions and architectures.


Smart health
Mobility/ Wi-Fi
Open data
Smart farming/ agriculture
Smart grid/ energy/ utilities
Smart manufacturing
Smart/ digital citizens
Smart buildings
Smart transportation
DATA CENTRE
PRODUCTION
THE INTERNET OF THINGS


10 ms
Latency
7.2 Exabytes/ month
Data traffic
1 Gb/s
Peak data rates
4G
3 GHz
Available spectrum
100 thousand connections/Km²
Connection density
5G
Latency
< 1 ms
Data traffic
50 Exabytes/ month (2021)
Peak data rates
20 Gb/s
Available spectrum
30 GHz
Connection density
1 millions connections/Km²

Central Cloud Data Center



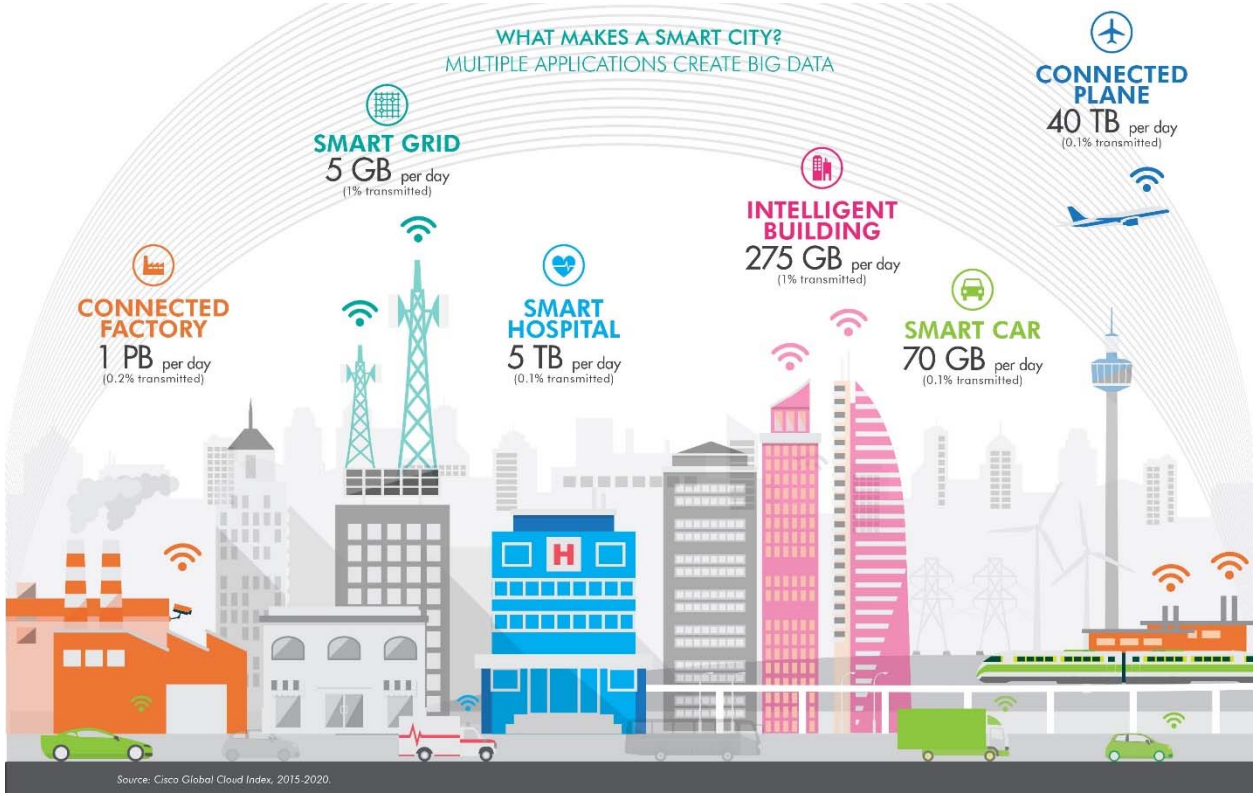
Backhaul to the Internet

Network Edge Data Center

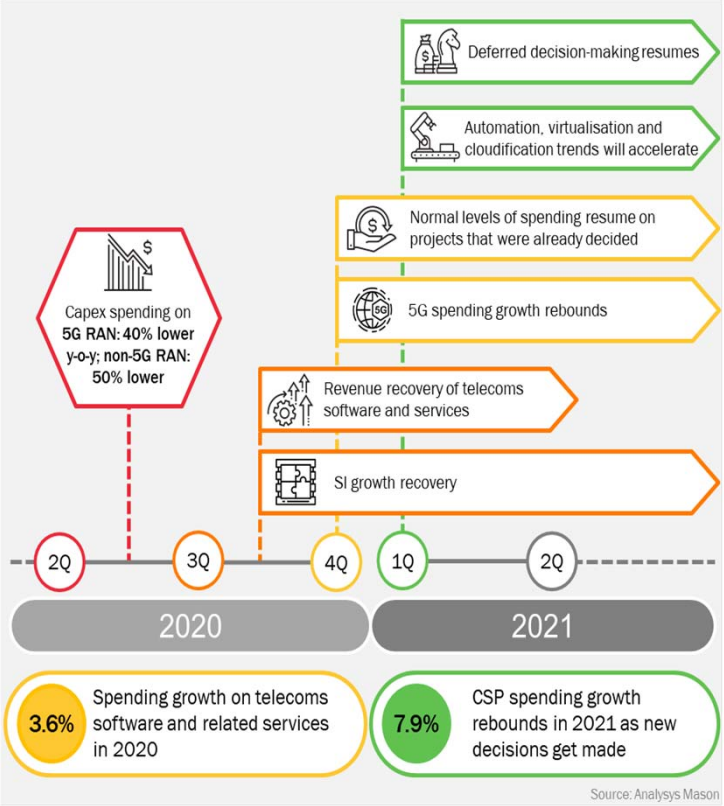
Customer & Application Edge

Latency > 100ms — **~ 20ms** — **< 10ms**

At the Heart of the Smart City



"COVID-19 reinforces the value of network connectivity and of the cloud-deployed services that amplify the value of the network." - Analysis Mason



In The New Normal

Overarching Themes:

- Remote Workforce
- Remote Learning – redefining college and advanced learning
- Resiliency and Reliability – critical infrastructure investment and stable supply chain
- Financial Uncertainty – road to recovery will be long and slow for some verticals
- Highspeed Broadband Access – necessity of life
- Emerging / Accelerated Pull Applications:
  - Telemedicine
  - Drone Tech – delivery, surveillance
  - Digital Banking
  - AI / ML
  - Remote Collaboration Platforms
  - E-Commerce
  - Industrial IOT

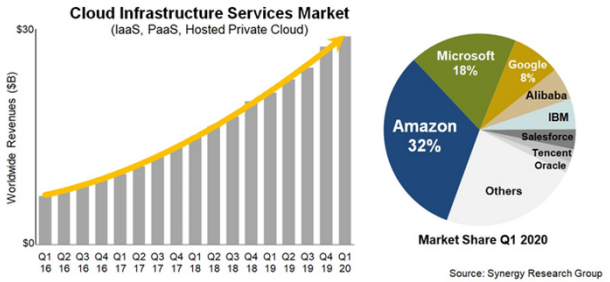
Ref "C19: Only Short Term Impact..." :: Analysis Mason

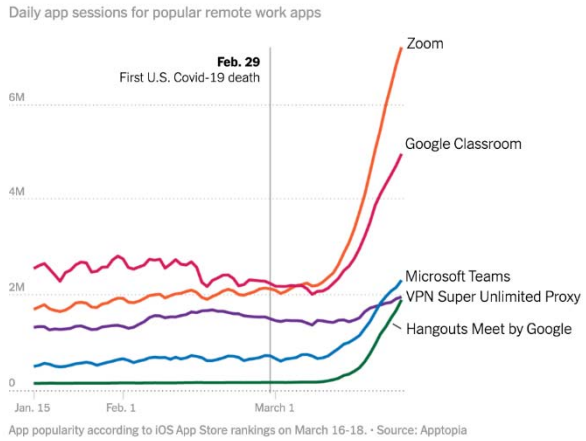
*"Despite recent market uncertainties, we anticipate the Tier 1 cloud service providers to **increase data center capex** as planned, primarily on servers, as the sector seeks to resume capacity expansion." - Fung, Dell'Oro*

In The New Normal

- Internet Traffic increase expected to drive ongoing and accelerated investment in data center and network infrastructure
  - LightCounting updated forecast for 100GbE transceivers showing accelerated growth over pre-COVID models
  - Microsoft states that it has seen a 2-year digital transformation in the span of 2-months.
  - Demand on Azure services outpaced overall market by 20% and Microsoft overall share grow by 3% in Q1
- Alibaba announced a $28B infrastructure investment over next three years which would firmly establish them in the Top 6

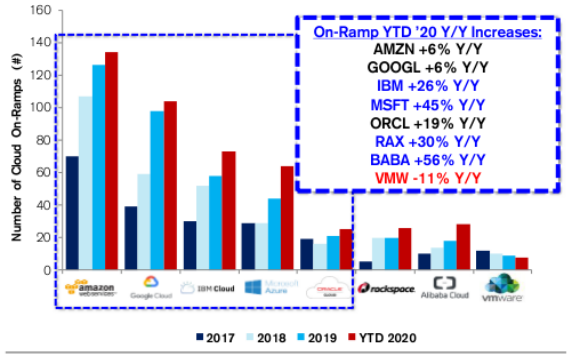
"If nothing else, these past few months have truly ushered in a new era in technology, where we are seeing a fundamental shift in how everyone is feeling, not only the technology itself but how to access that technology, as well as how we built the technology," – Vogel, AWS



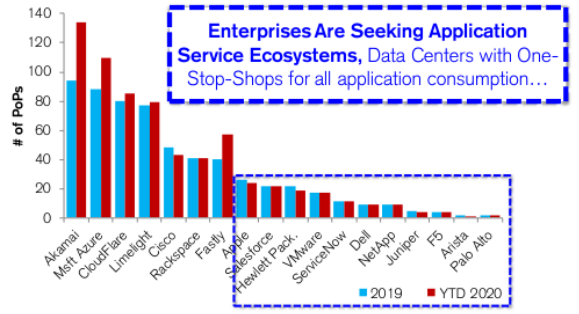


COVID and Colocation

- Strong growth in Cloud On-Ramp investments through first 5 months of 2020
  - Microsoft led growth with a 45% YoY increase in on-ramp nodes
  - Seeing strong drive by Fortune 2000 Companies to more aggressively adopt colocation strategies
- Similar growth observed in SDN On-Ramp investments
  - PacketFabric saw 18% YoY growth in on-ramp nodes
- Most MTDCs have maintained 2020 Guidance indicating overall confidence in outlook for 2020
  - Many MTDCs reporting highest ever quarter-end backlog
- Overall trends providing Multi-Tenant Data Centers (MTDC) accelerated growth over Pre-Covid estimates



Source: Credit Suisse Estimates, Cloudscene, Inflect, Company data.



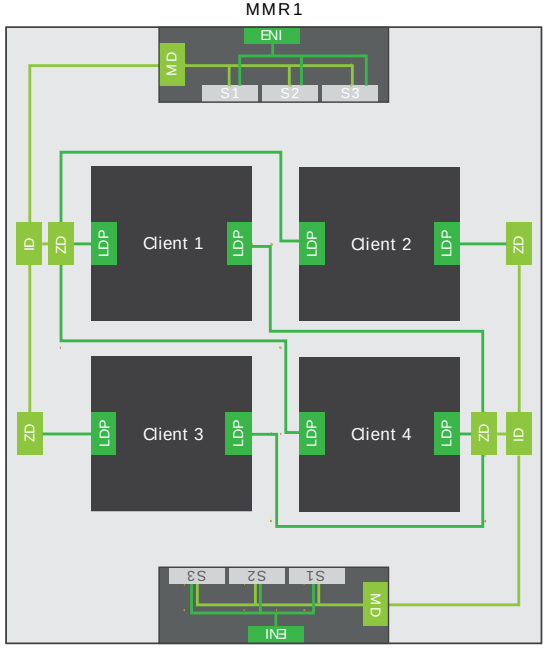
Source: Credit Suisse Estimates, Cloudscene, Company data.

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

Basic Data Center Model

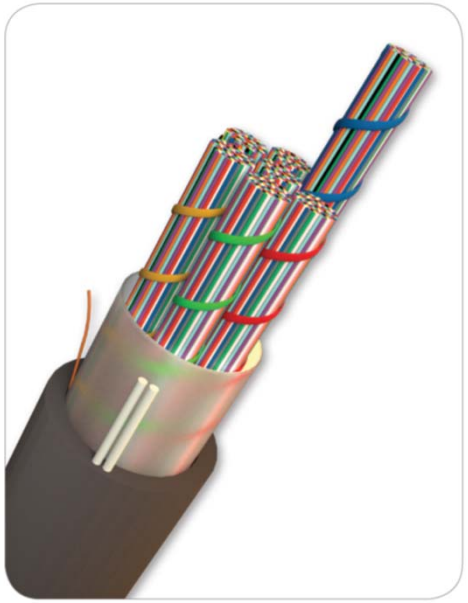


Courtesy: AFL Hyperscale

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



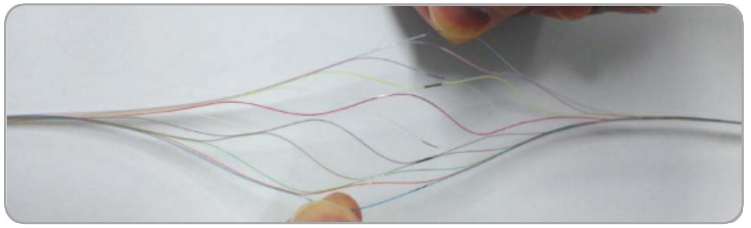
Leading Cable Characteristics

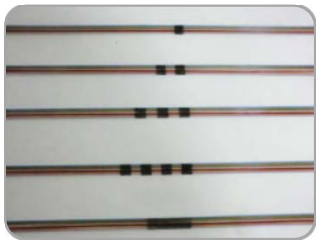
Latest Generation Ribbon

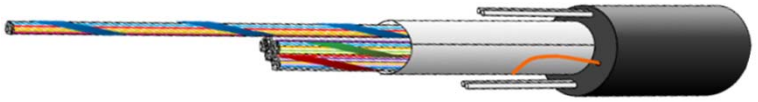
- Promotes use as Ribbon or Loose Fiber
  - Enables Mass Fusion splicing, or Individual splice connections
  - Maximizes use of space in cable core
- Clear Organization

Smallest Diameters

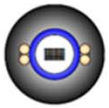
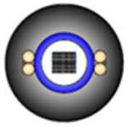
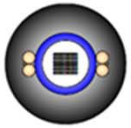
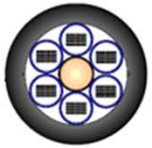
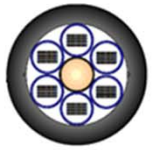
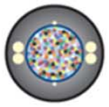
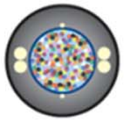
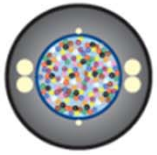
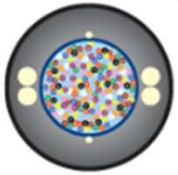
- Maximize pathway utilization
  - High Fiber Counts





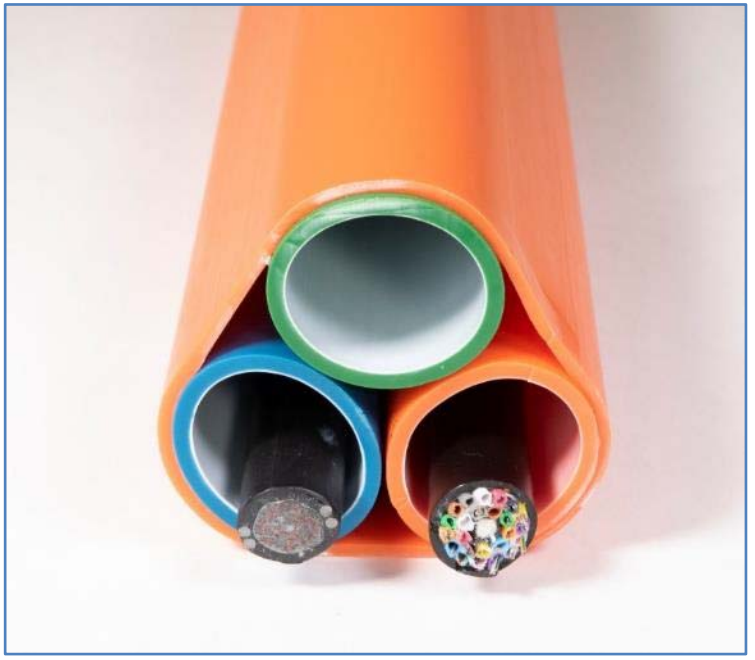


Latest Generation Ribbon Cable Size Advantage over Traditional OSP Cable Designs

	144F	288F	432F	864F	1,728F	3,456F	6,912F
Loose Tube Cable	 16.0 mm	 18.9 mm	 21.0 mm	—	—	—	—
Ribbon Loose Tube Cable	 13.9 mm	 19.8 mm	 19.8 mm	 25.1 mm	 25.4 mm	—	—
Flexible Ribbon Cable	 10.5 mm	 12.0 mm	 13.5 mm	 17.5 mm	 23.0 mm	 26.5 mm	 35.0 mm

Pathway Use Example

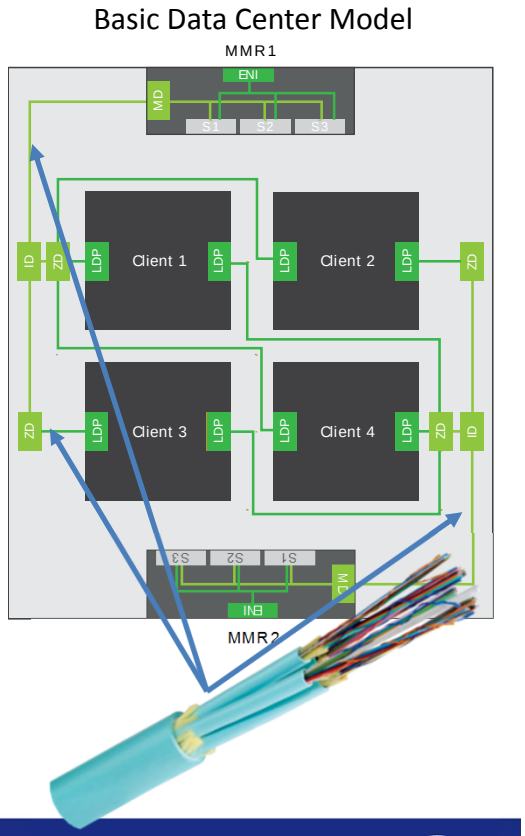
- Latest Generation Ribbon vs Conventional Loose-tube
  - Illustrates the impact of the evolution in design
  - 3 – Way, 1.25/1.50 in Microduct system measuring 3.0 in Diameter
  - 288ct Traditional Loose-Tube
  - 864ct Ribbon
    - Same density in one Microduct accomplished with 3 x 288ct in Traditional!



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

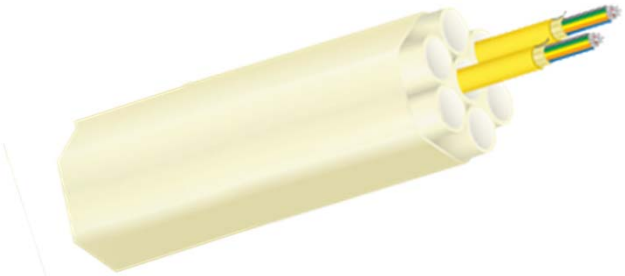
Latest Generation Ribbon (base building block)

- 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:

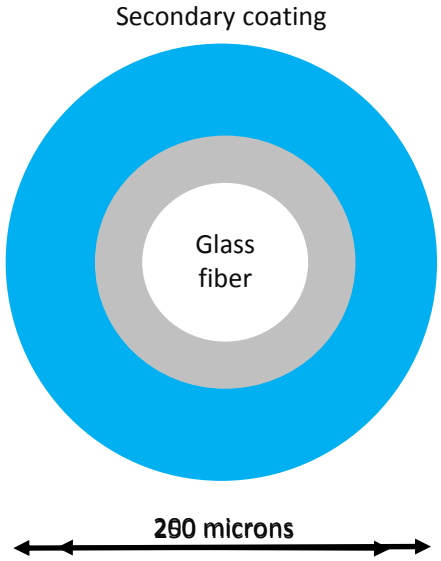
- Individual pathways
  - Enhances Security
  - Minimizes post-install access requirements
  - Configure to specific needs
  - Easy moves, adds and changes
- Air-assist installation
- Ribbon construction
  - Mass Fusion splicing



Next Evolution in Density/Pathway Utilization

200um Single-mode Fiber (SMF)

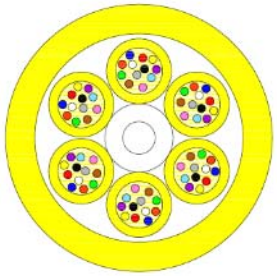
- ITU G.652, ITU G.657 grade, backwards compatible
  - Single Fiber and Flexible Ribbon options
- Core, Cladding dimensions match current 250um infrastructure
  - Strip, Clean, Cleave process are similar to current best-practice
- Further reduces the impact of the passive cabling infrastructure
  - 35% 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



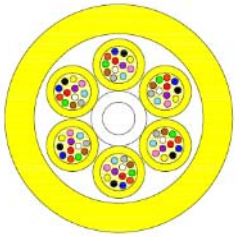
Courtesy: The Light Brigade

Next Evolution in Density/Pathway Utilization

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

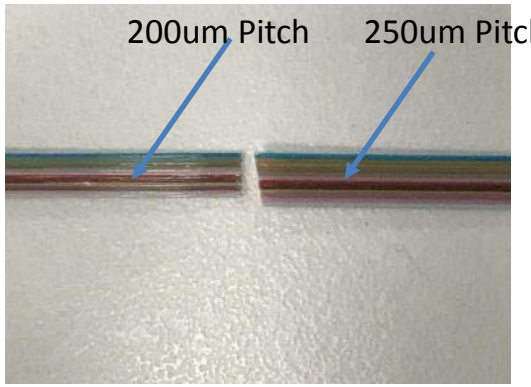


Current 72f – 8.2mm



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)

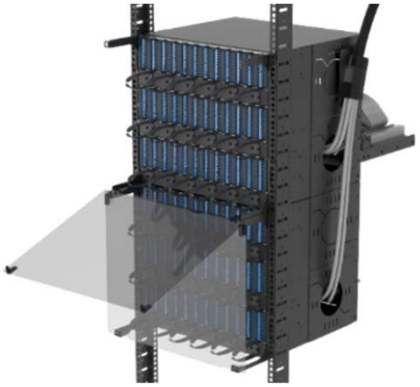
Challenge: High-Density Connectivity

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

6,912ct Wall/Rack Mount Splice

18,432F Splice Cabinet

Dedicated Patch and 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

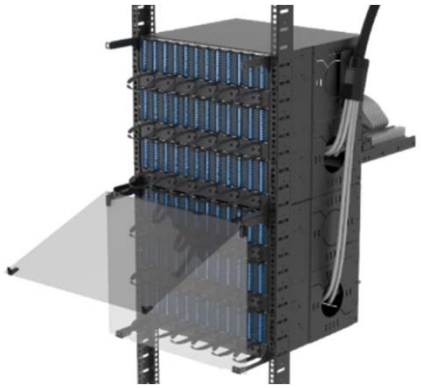
2RU 288 ct Panels

- 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?

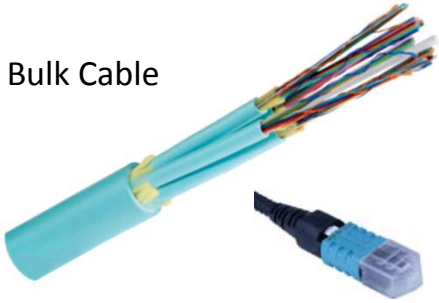
Dedicated Patch and Splice



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	Hyperscale
• 1GbE to 10GbE to 40GbE	• 25GbE to 100GbE and beyond
• Up to 150 meters	• 500 meters to 2 km
• Multimode meets most needs	• Single-mode meets the current needs, and can meet future requirements

• Parallel optics to meet increased bit rates
  • MPO connectors
	• Increase serial speed to 100GbE+ and parallel speed to 1TbE
	  • MPO

• Shortwave wavelength division multiplexing (SWDM) with OM5 presents new growth path	• Course and Dense Wavelength Division Multiplexing (CWDM and DWDM) • Duplex LCs

Standards Based Data Rate Migration Path to 400GbE on MMF

Change cable assemblies?

Most likely
Not required

IEEE 802.3 Link Distance (meters)

Multimode Fiber Type	10GbE	40GbE		100GbE		400GbE*	
OM1	33 m						
OM2	82 m						
OM3	300 m	100 m	(SR4 4x10G)	100 m 70 m	(SR10 10x10G) (SR4 4 x 25G)	70 m	(SR16: 16x25G)
OM4	400 m	150 m	(SR4 4x10G)	150 m 100 m 100 m	(SR10 10x10G) (SR4 4 x 25G) (SR2 2 x 50G)	100 m XX	(SR16: 16x25G) (SR4: 4x100G)*
OM5 **	400 m	150 m	(SR4 4x10G)	150 m 100 m	(SR10 10x10G) (SR4 4 x 25G)	100 m XX	(SR16: 16x25G) (SR4: 4x100G)*

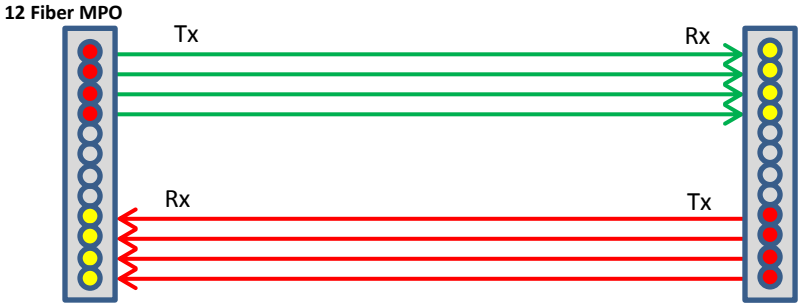
* Future

** 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

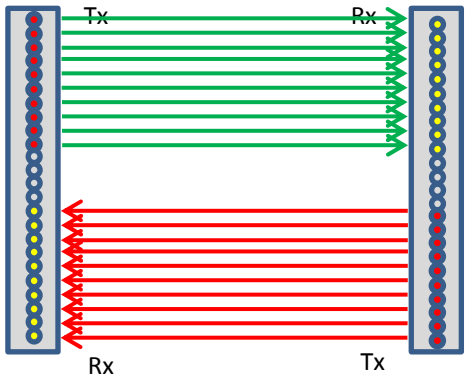


Multimode Migration Path in Data Centers
40 GbE to 100 GbE (using 10 GbE Laneways)

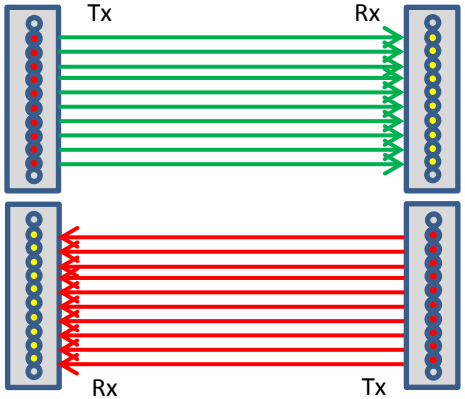
- 100 GbE (10 x 10 GbE parallel optics) – 1st generation
  - OM3 VCSEL 100 meters 20 Fibers
  - OM4 VCSEL 150 meters 20 Fibers

Replace transceivers and cable assemblies

24 Fiber MPO

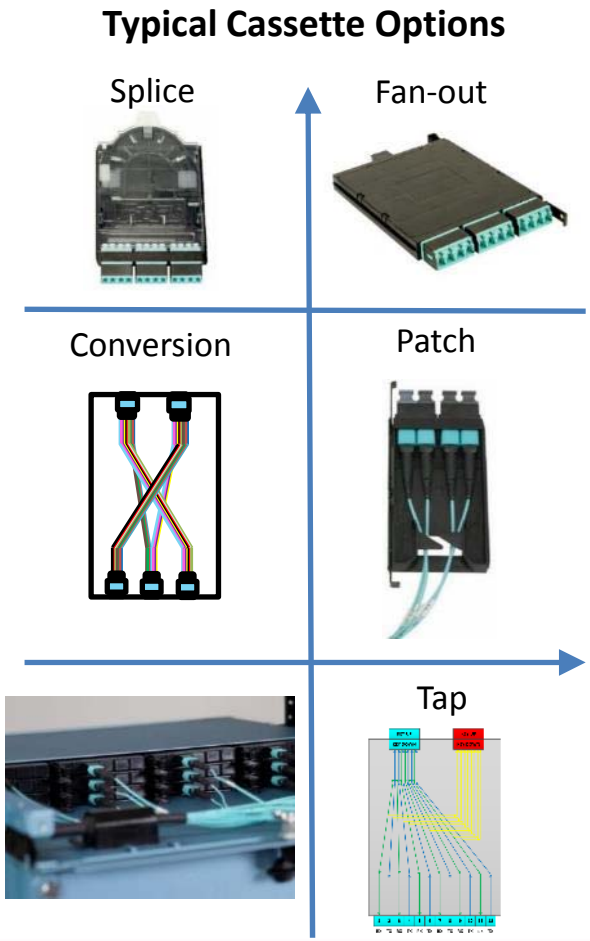


2 x 12 Fiber MPO



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

MPO/MTP® terminated Trunk

Patch Cord

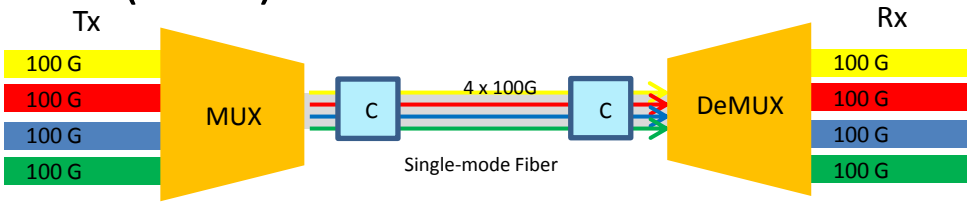
- Small diameter construction
- Terminated with Reversible Connectors
- Enhanced handling with push/pull features

Uniboot terminated Patch Cord

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



HIGH DENSITY CABLE and FIBER MANAGEMENT

Q&A

with

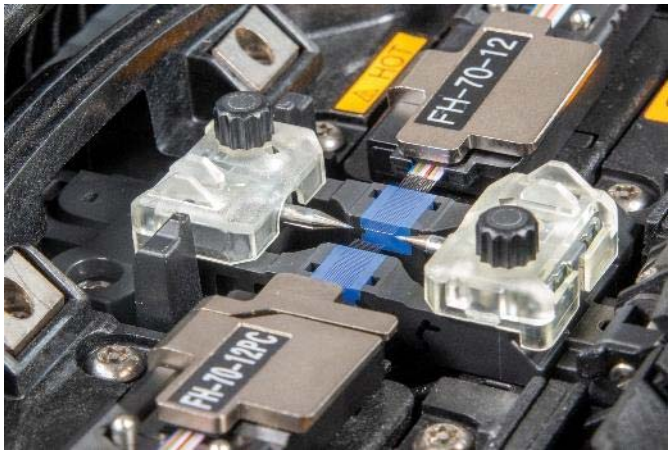
KEVIN CLAYTON

Lucas Mays

LOW LOSS, RAPID SPLICING – WHAT MODERN DATA CENTERS DEMAND

Rapid Splicing = Mass Fusion Splicing

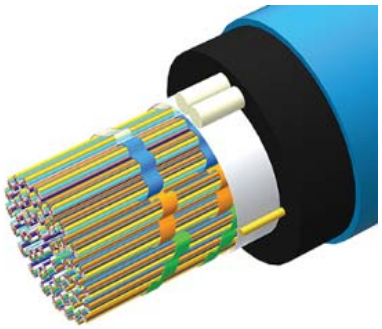
- Mass Fusion Splicing
  - Any time you are preparing and splicing multiple fibers at a single time - range is from 2 to 12



- 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 73% reduction in splice time
- As fiber counts increase, single fiber splicing becomes unrealistic



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- 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

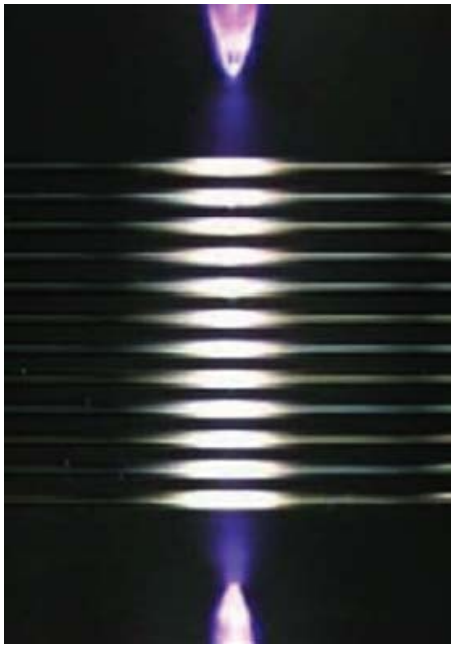
Fiber Combination	Average Splice Loss (dB)	Standard Deviation	Maximum Splice Loss (dB)	Minimum Splice Loss (dB)
G.657 #1 to G.657 #2	0.03	0.014	0.07	0.00
G.657 #1 to G.652.C	0.02	0.019	0.13	0.00
G.657 #1 to G.652.D	0.02	0.014	0.05	0.00
G.657 #2 to G.652.C	0.03	0.013	0.07	0.00
G.657 #2 to G.652.D	0.02	0.017	0.08	0.00

Reference:
David W. Mansperger, Douglas M. Duke, Lucas C. Mays, "Mass Fusion Splicing of Dissimilar Fibers" Proceedings of the 67th IWCS, 2018

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

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

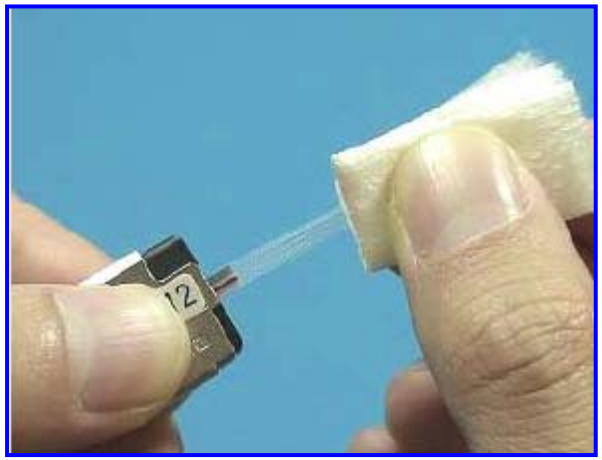


Low Loss – What it Takes

- 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. - repeatable 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

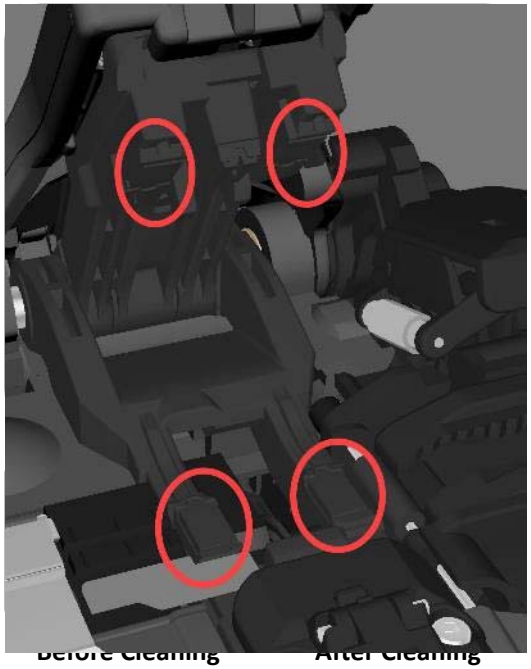


Pain (Points) Management – Cleanliness

- 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

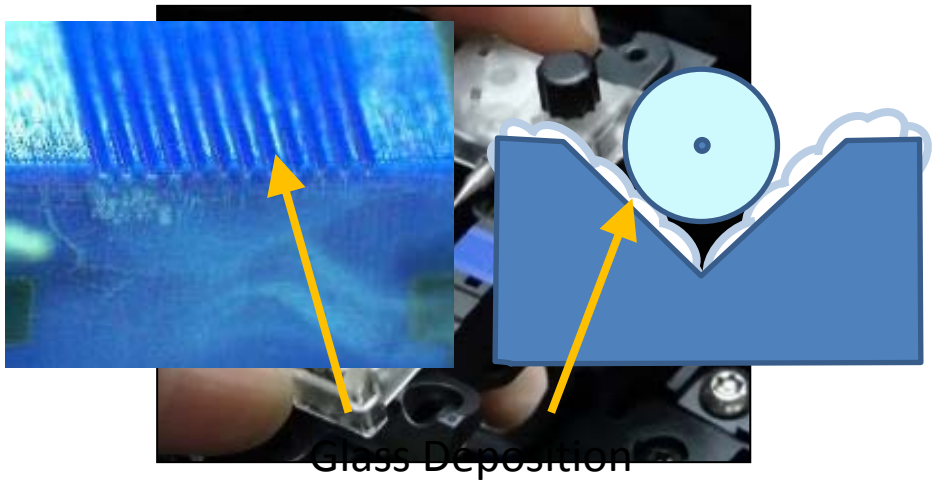
- Splicer V-grooves require periodic cleaning at minimum
  - Or when large pre-splice offsets appear and re-prepping the ribbon does not resolve
  - Special kits exists for Mass Fusion v-groove cleaning
  - Absolutely a requirement for quality work
- Fiber holders and cleaver clamp pads also need to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



Before Cleaning After Cleaning

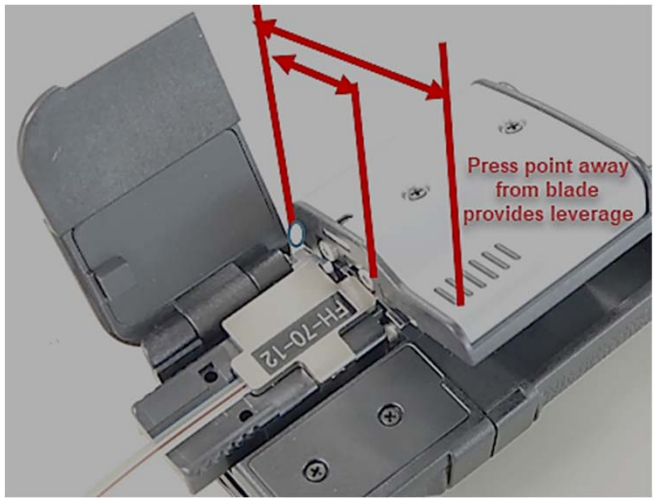
Pain (Points) Management – Cleanliness

- Even if cleanliness is well maintained, silica from fibers will accumulate on V-grooves over time
- This causes high pre-splice offsets which lead to poor splice performance
- Sending splicer in for service is required to resolve
- Some splicers possess replaceable V-grooves, so cleaning or service can be postponed until a more convenient time



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

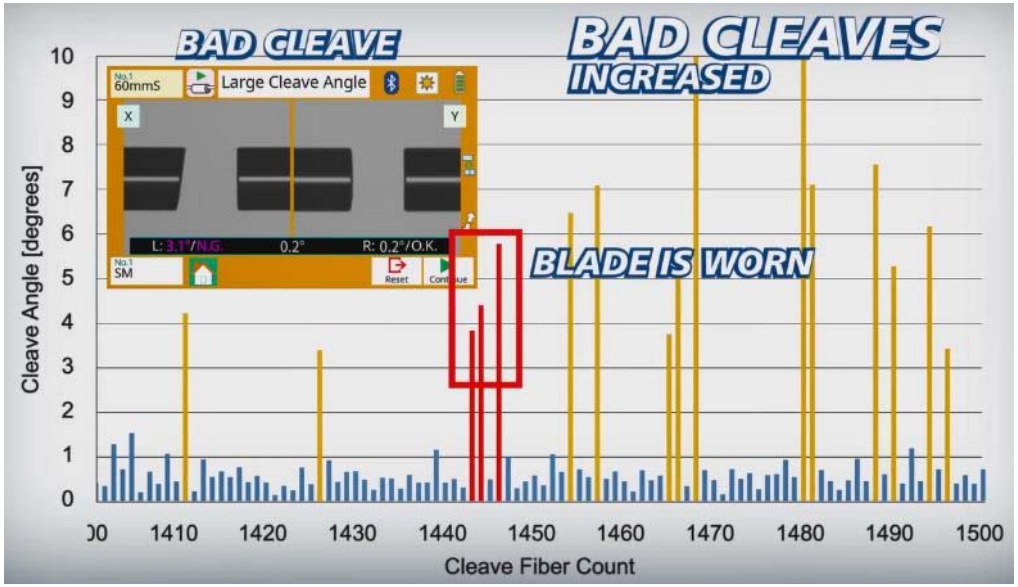


Pain (Points) Management – Cleaver Blade

- 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

LOW-LOSS, RAPID SPLICING

Q&A

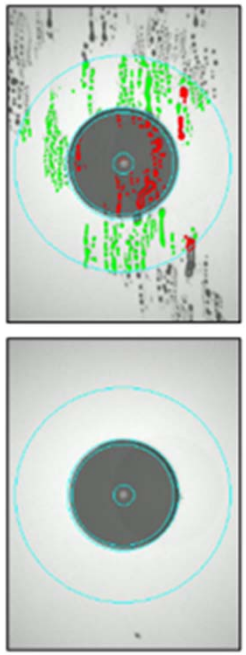
with

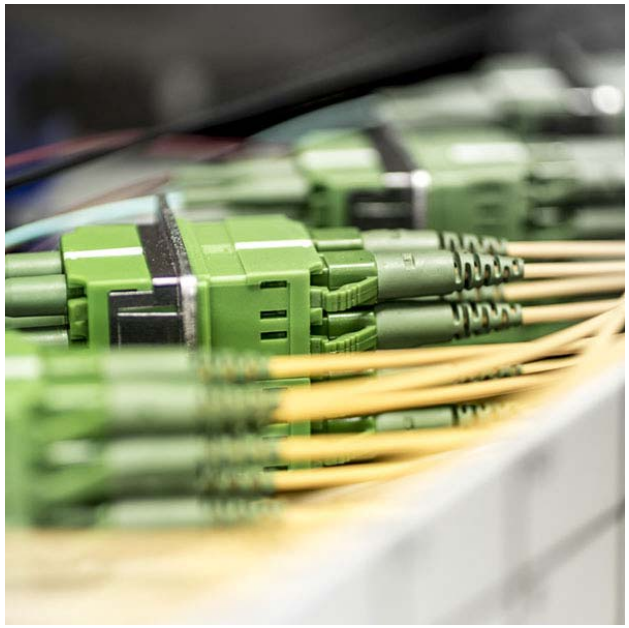
LUCAS MAYS

CLEAN FOR SUCCESS

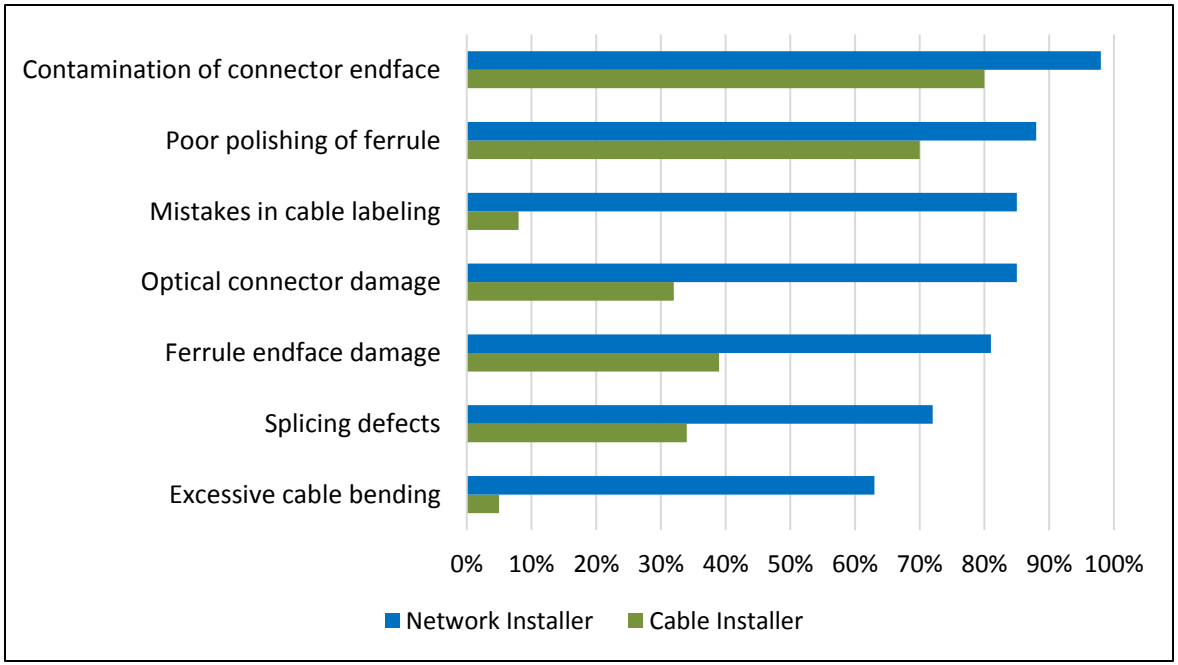
Why Does It Matter

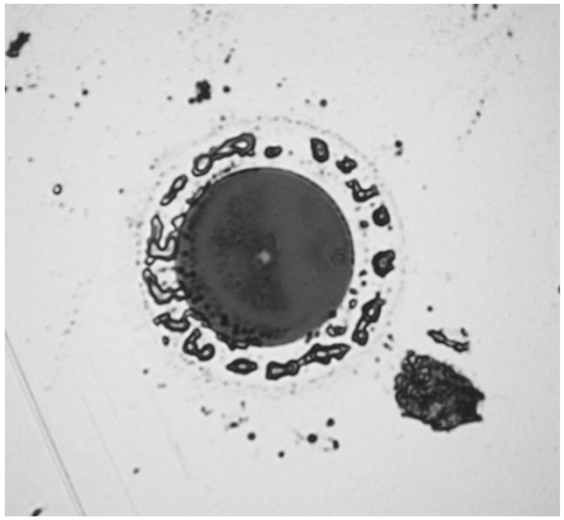
- Why Clean?
- Why Inspect?
- Isn’t it clean out-of-the-bag?





#1 Problem: Dirty / Damaged Connectors



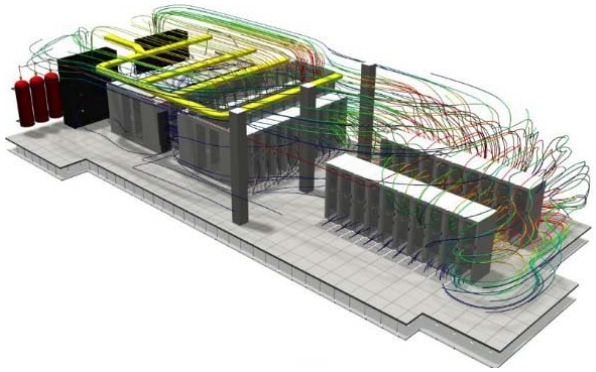


- "98% of installers and 80% of network owners reported that issues with connector contamination were the greatest cause of network failure" – *NTT Advanced Technology*

Fiber Optic Connector Inspection – Why?

HVAC systems move large volumes of air to cool IT equipment

Data Centers are ***NOT*** clean environments



…and along with the cool air, **Dirt Particles** also move!

Fiber Optic Connector Inspection – Why?

ISO 14644
Cleanrooms and associated controlled environments

CLASS	Max concentration limits (particles/m3 of air) for particles ≥ than the sizes listed below					
	0.1 micron	0.2 micron	0.3 micron	0.5 micron	1 micron	5 micron
ISO 1	10	2				
ISO 2	100	24	10			
ISO 3	1,000	237	102	35	8	
ISO 4	10,000	2,370	1,020	352	83	
ISO 5	100,000	23,700	10,200	3,520	832	29
ISO 6	1,000,000	237,000	102,000	35,200	8,320	293
ISO 7				352,000	83,200	2,930
ISO 8				3,520,000	832,000	29,300
ISO 9					8,320,000	293,000

Class 7 allows up to 29k **5-micron** particles per m^3 of air

Data Centers typically Class 7

Fiber Optic Connector Inspection – Why?

Shrinking Loss budgets

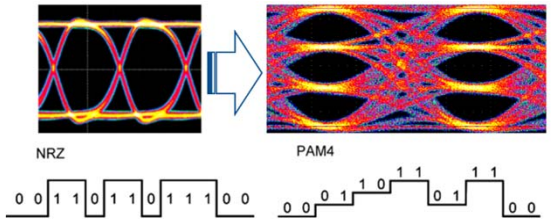
- New "-DR" single-mode applications have significantly lower loss budgets

SPEED	STANDARD	Singlemode	
		Loss Budget (dB)	Distance
10G	10GBASE-LR	6.0	10 km
40G	40GBASE-LR4	6.7	10 km
100G	100GBASE-DR	3.0	500 m
	100GBASE-LR4	6.3	10 km
200G	200GBASE-LR4	6.3	10 km
400G	400GBASE-DR4	3.0	500 m
	400GBASE-LR8	6.3	10 km

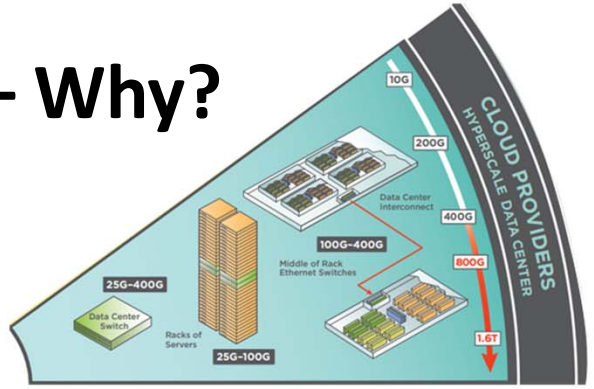
- MM Ethernet and Fiber Channel budgets also reduced

New technologies more susceptible to insertion AND return loss

- PAM4 encoding for 100G and higher speed applications



Fiber Optic Connector Inspection – Why?

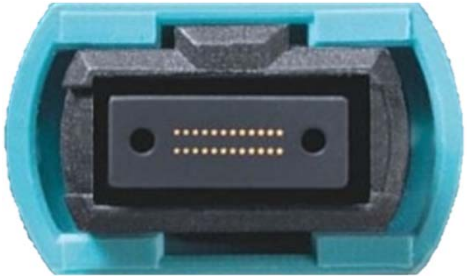


More Bandwidth per fiber:

- 400G standards complete (IEEE 802.3bs, cm and cn)
- 800G work is underway with Terabit ethernet on the horizon

More fibers per connector

- MPO-12 and MPO-24 deployed today
- MPO-16 and MPO-32 in process
- Standard allows for up to 72 fibers



More at stake per connection

- Cost of unplanned outages nearly $9,000/ minute

Fiber Optic Connector Inspection – Why?

Workforce changes, OPEX reduction, and verification

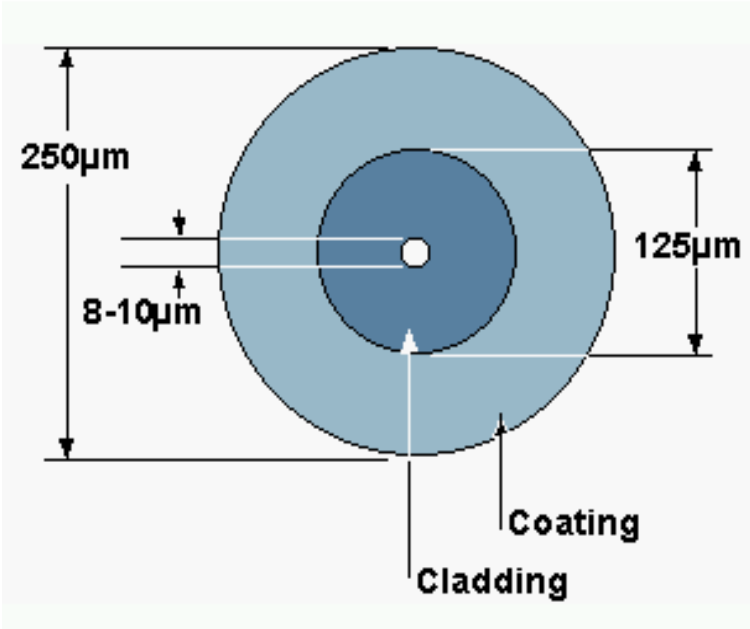
- Increasingly, network turn-up and maintenance tasks are outsourced to companies whose technicians might have limited fiber experience
- Constant pressure to reduce operating expenses
- Need visual proof that work was done
  - Trust but verify

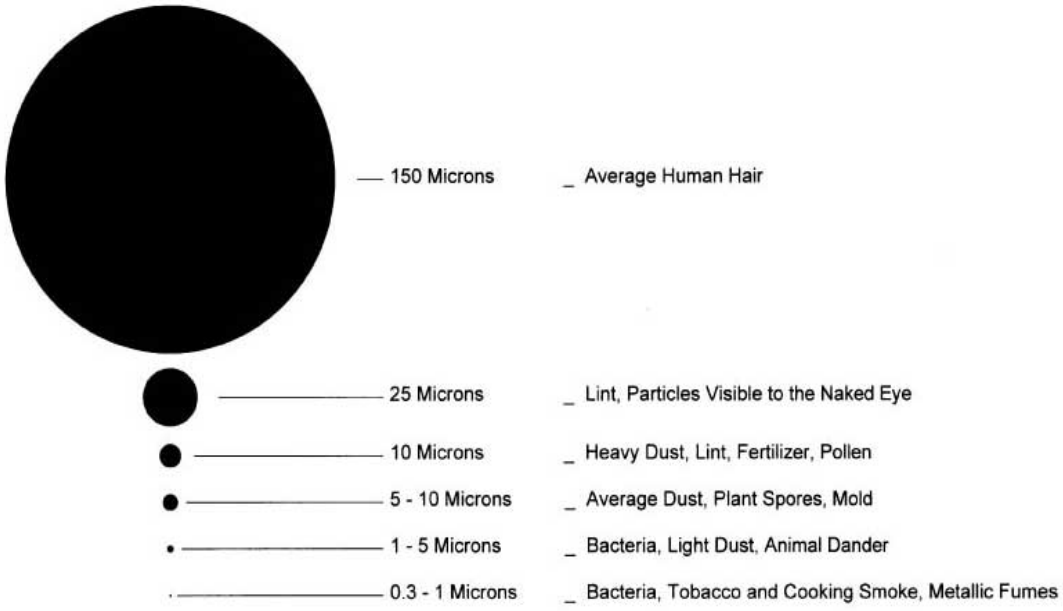
Simple, fast endface inspection tools address these issues

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

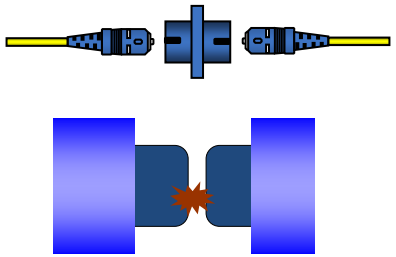


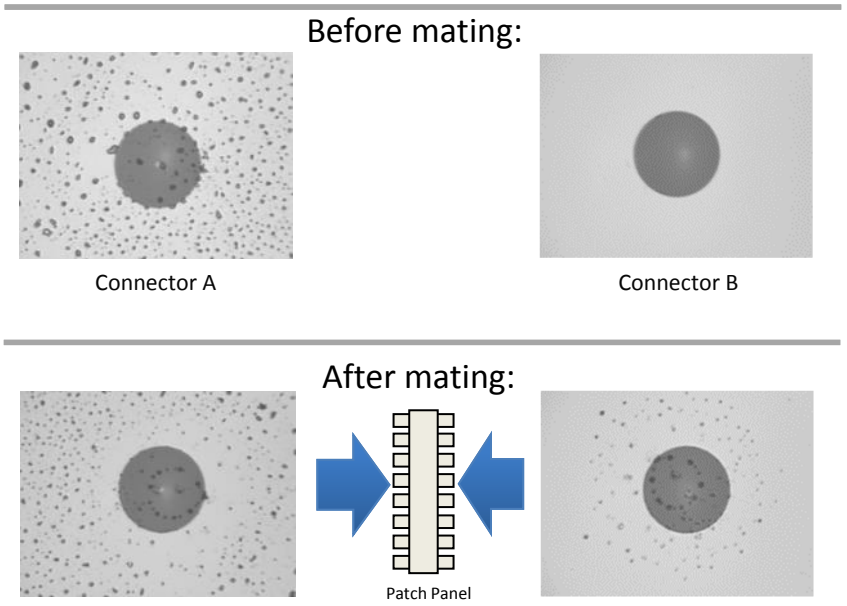


Importance of Cleaning & Inspection

Dust/dirt residue transfer

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

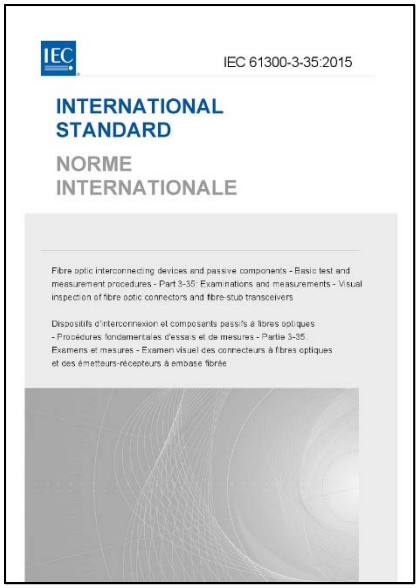




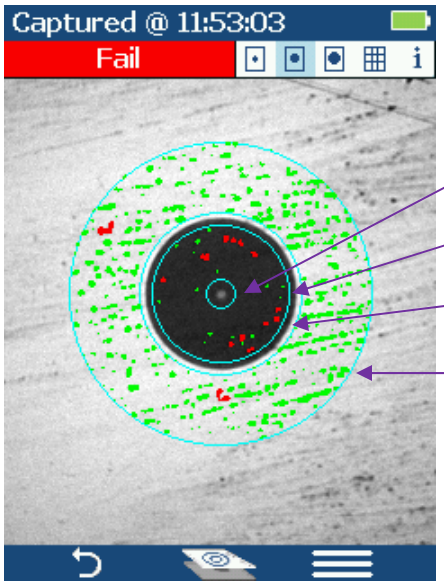
Standards for Auto-Analysis of Endfaces

International standards for auto-analysis

- IEC 61300-3-35 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 2021, with MPO/MTP inspection optimizations



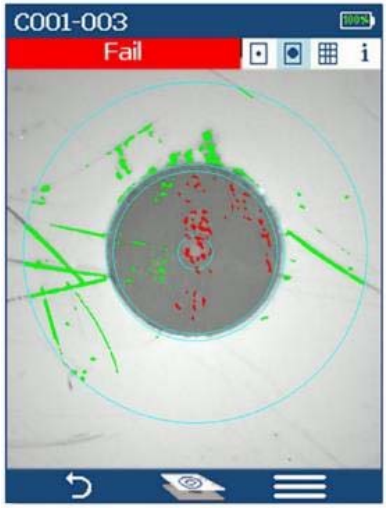
Automated Pass/Fail to IEC Std



Zone[a]	Scratches (maximum number of a given dimension)	Defects (maximum number of a given dimension)
A: core 0 µm to 25 µm	None	None
B: cladding 25 µm to 115 µm	No limit ≤ 3 µm None > 3 µm	No limit < 2 µm 5 from 2 µm to 5 µm None > 5 µm
C: adhesive 115 µm to 135 µm	No limit	No limit
D: contact 135 µm to 250 µm	No limit	None > 10 µm
NOTE 1 There are no requirements for the area outside the contact zone. Cleaning loose debris beyond this region is recommended good practice. This is of particular concern for multiple-fibre rectangular-ferrule connectors. NOTE 2 For multiple-fibre rectangular-ferrule connectors, the criteria apply to all fibres in the array.		
[a] For multiple-fibre rectangular-ferrule connectors only the requirements of Zone A and Zone B apply.		

- Limits set for each zone
- Automated analysis simplifies and speeds up pass/fail

Cleaning & Inspection Best Practice: ICIC Method



START

INSPECT ENDFACE

High Resolution Digital Scope

Using appropriate Tips for Connector Type

ENDFACE CLEAN?

PASS

PLUG INTO CLEAN MATING CONNECTOR

FAIL

DRY CLEAN

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

INSPECT ENDFACE

ENDFACE CLEAN?

PASS

PLUG INTO CLEAN MATING CONNECTOR

FAIL

FCC2
FiberWipes
CleanWipes
CCT Tips
CLETOP Sticks

WET / DRY CLEAN

FAIL

INSPECT ENDFACE

ENDFACE CLEAN?

PASS

PLUG INTO CLEAN MATING CONNECTOR

"Inspect Before You Clean"
IBYC

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
- If clean – connect!

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
- Use dry cleaning as first option
  - Effective, but not perfect

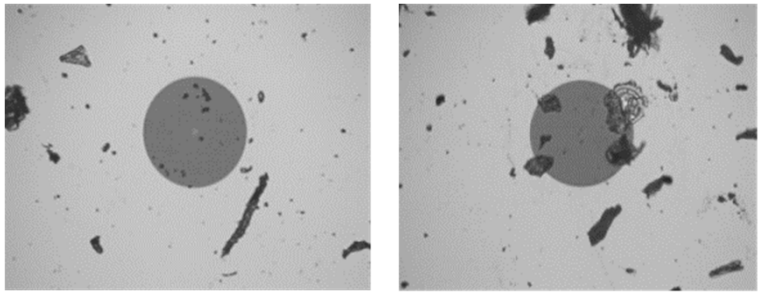
Step 3 – Inspect (again)

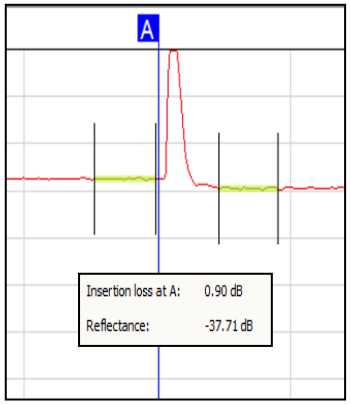
After cleaning you need to inspect **all** end faces in the connector again

- 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

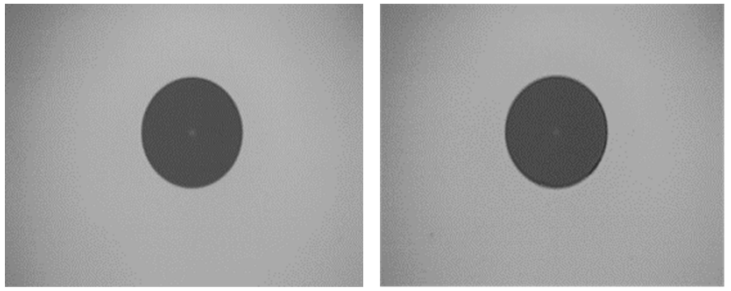
Clean Connectors Matter!

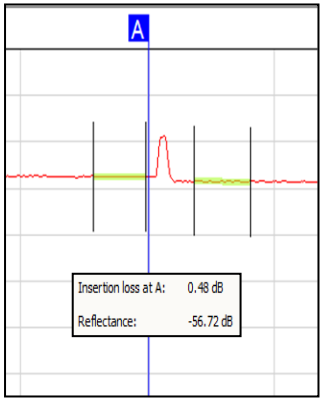
Dirty connectors = high insertion loss and high reflectance



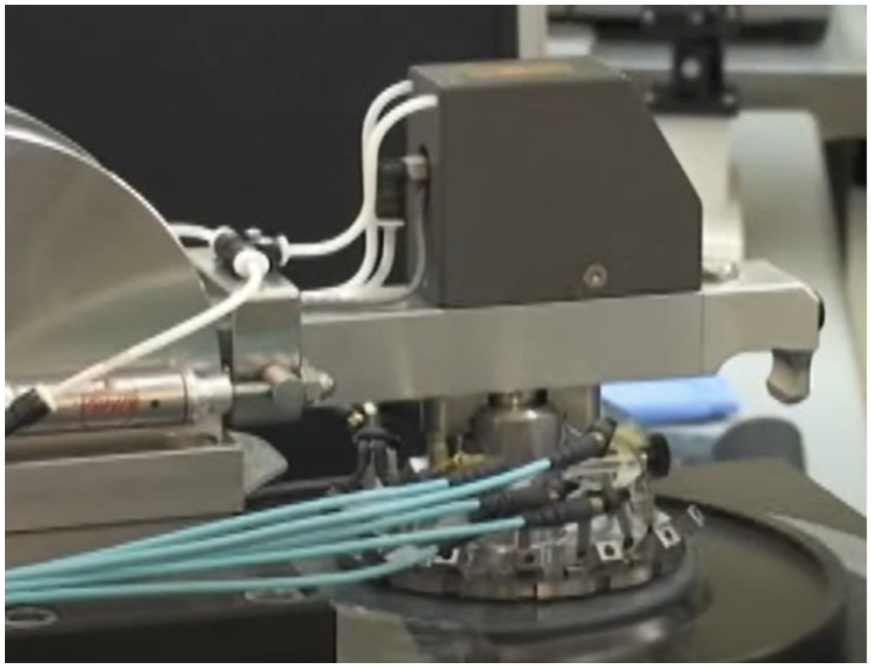


Clean connectors = low insertion loss and low reflectance





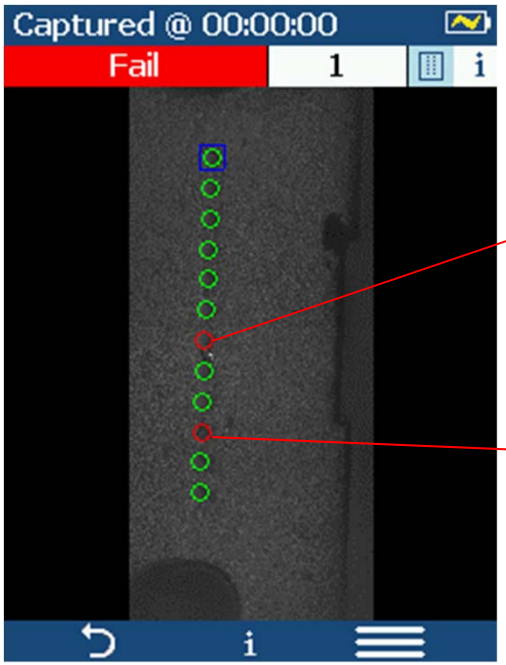
MPO Factory Terminations: New Does Not Equal Clean

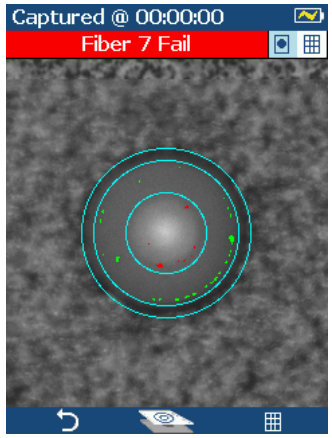


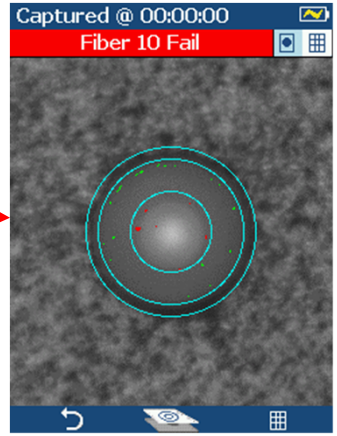
- MPO cabling typically done in a factory, pre-terminated to length
- Perception that it is clean “right out of the bag”

New Does NOT Equal Clean

- Inspected “Factory New” multifiber connector
  - 2 out of 12 failed -
  - IEC 61300-3-35

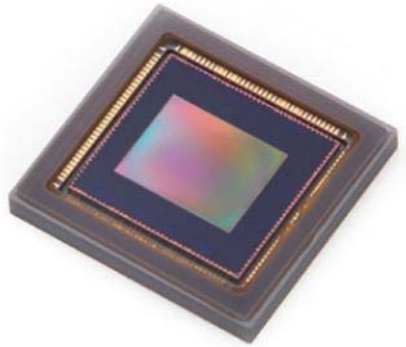






Auto-Analysis in a MPO World

- Many Handheld Microscopes use real-time image processing to automatically analyze endface surface conditions
- By leveraging the semiconductor sensors, microprocessors and memories found in modern smartphones, today's Inspection Scopes can achieve speed and accuracy
- New generation "Fast MPO" inspection probes can provide pass/fail analysis at 1 second/endface (12 fiber MPO in about 10 seconds)
- A fundamental breakthrough in speed and efficiency when compared to manual mechanical scanning methods taking 60 seconds per end-face

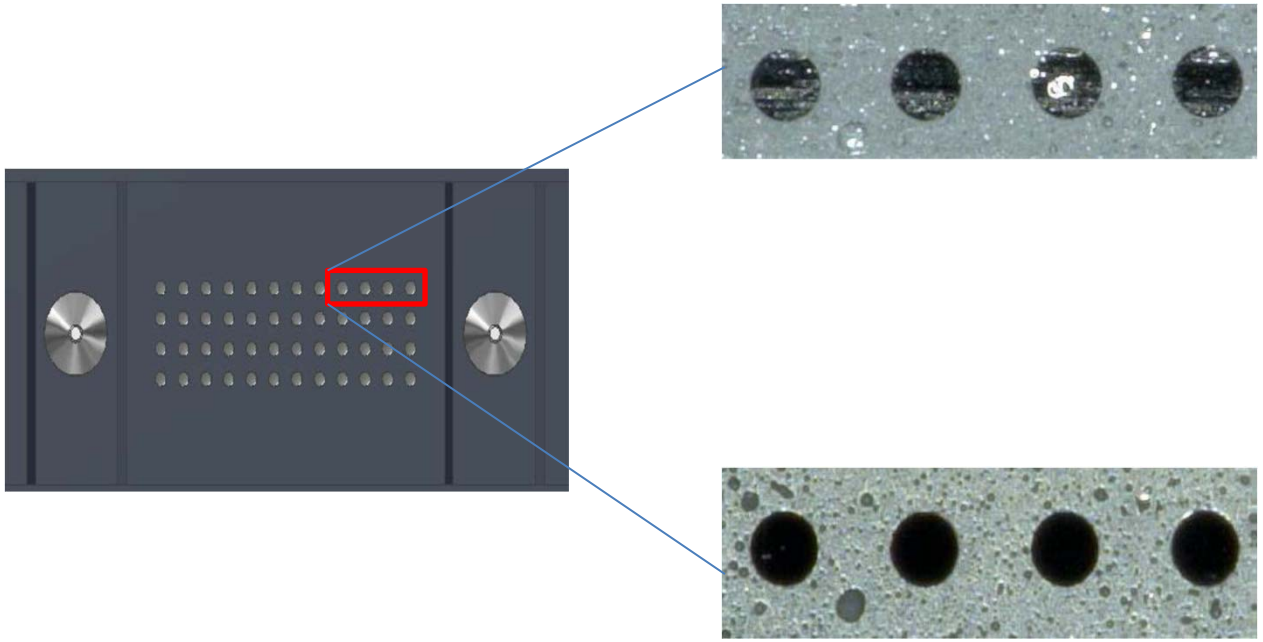


Inspecting Multi-Fiber Connectors

- 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

Multi-Fiber Connectors - MPO



The problem is multiplied

More fibers in same space

The MPO/MTP Challenge

- Achieving consistent or repeatable auto-analysis connector inspection results
- Endface surface textures and colors vary widely across connector vendors
- LED illumination level on the endface can vary dramatically based on polish and type
- Tolerance Limits on Alignment sleeves (sometimes called bulkhead adapters) and Adapter Tips stack-up

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 – <u>but 6.25 mm ferrule pitch does not meet next generation Ethernet switch needs</u>

Standard LC Duplex

Typical
Connector
Cleaner

LC APC & UPC
Bulkhead
Adapter Tips

APC and UPC
1.25mm Adapter Tips

Patch
Cord

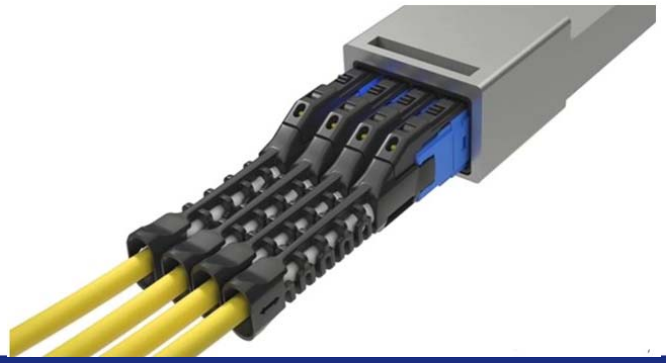
Typical
Single Fiber
Inspection
Scope

Emerging High-Density Duplex Connectors

- Senko and US CONEC have introduced new 1.25 mm ferrule duplex connectors with tighter mechanical dimensions – **3.1 mm ferrule pitch**

CS SN MDC

400G Transceiver



Eight 1.25 mm ferrules fit in one QSFP-DD transceiver faceplate = duplex 4x 100G single λ = 400G

Next Gen Connector Support

Bulkhead inspection example for MDC-UPC

Typical
Wireless
Multi-Fiber
Inspection
Scope

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

Cleaners for HDD connectors

CLEAN FOR SUCCESS

Q&A

with

SEÁN ADAM

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….

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

Kevin Clayton

Lucas Mays

Seán Adam

Q&A

THANK YOU