Optimum Fiber Types for Outdoor and Indoor Access Deployments

CORNING

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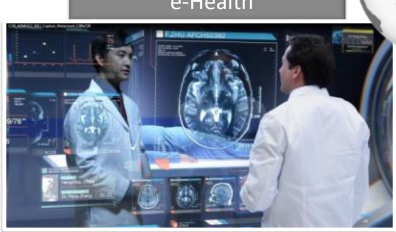
The Benefits of High Speed Broadband Are Widespread

e-Education

e-Working

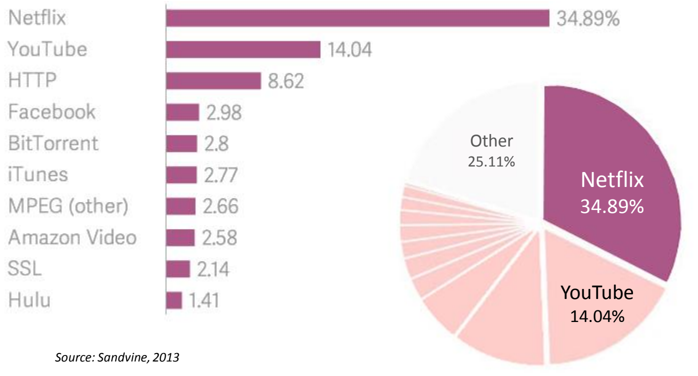
e-Health



e-Entertainment

Video Streaming in the House Is the Leading Consumer of Bandwidth…

Top Online Bandwidth Usage Sources in North America
(During peak periods and fixed access only)



Source: Sandvine, 2013

… and the Internet of Things (IoT) or the next big data wellspring is around the corner..

The Internet of Things

- The Internet of Things is numerous everyday objects – e.g. sensors - connected wirelessly to the internet
- By the end of this decade:
  - 50 billion of those devices will be connected by 2020
  - Generating 1000 times as much data as today's mobile gadgets
  - At rates 10-100 times faster than existing speeds

Source: IEEE Spectrum News Report June 2013

- A Dutch start-up (Sparked) is using wireless sensors on **cattle**
- Each cow generates 200Mb per year

- Once things start to talk to each other they will also develop their own intelligence…
  - … Your meeting is delayed by 45 mins
  - … but your car needs fuel and its 5 mins to fill up the tank
  - … and there is 15 mins delay in your route

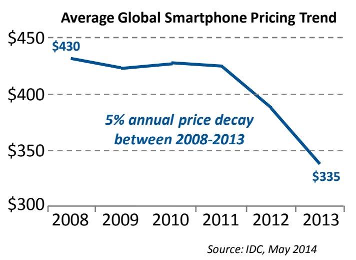
- Your alarm clock receives all this information allowing you 5 extra mins sleep

Source: Cisco: Internet Of Things Website

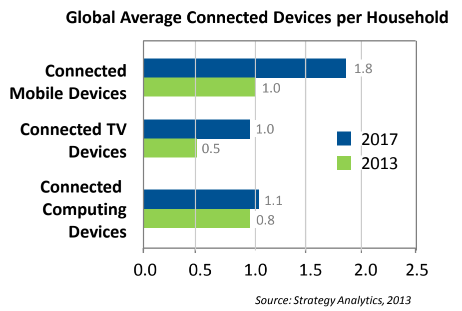
The Virtuous Circle of Data Generation

- Data rich video applications and user generated content deliver a more compelling product

- Prices of devices and subscription packages continue to decline increasing availability to masses



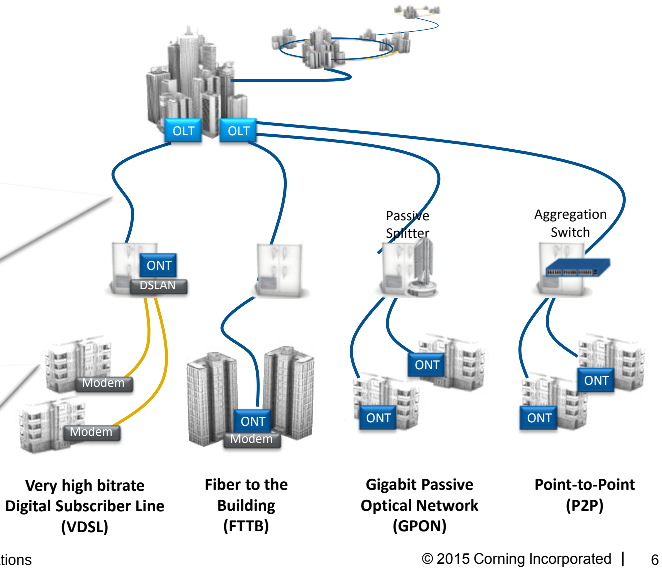
- Connected houses encourage more simultaneous connections



There is an average of 6 connected devices per internet household in US creating content as well as consuming bandwidth

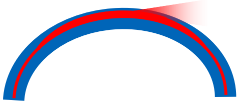
Source: NDP group/Connected Intelligence

What Matters When Fiber Approaches The Home?

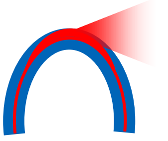


Which Optical Fiber Parameters Matters Most?

- With Macrobending the optical signal leaks out of the fiber at bends reducing the signal strength



Moderate loss with moderate bends



Increased loss with tighter bends

The Macrobend Improved Fibers

ITU-T G.657 standard

- ITU-T G.657 recommendation defines two categories of fibers:
  - **Category A**, is fully-compliant with the ITU-T G.652 single-mode fibers and can also be used in other parts of the network
  - **Category B**, is not necessarily compliant with ITU-T G.652, it is capable of low macrobending loss at very low bend radii and is pre-dominantly intended for in-building use

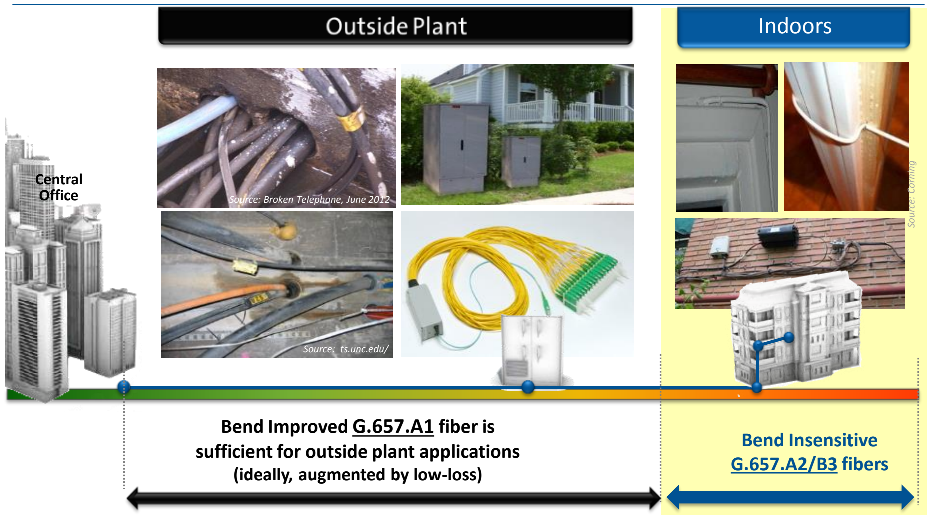
Minimum specified bend radius	ITU-T G.657 Recommendation	
	Category A (G.652 compliance required)	Category B (G.652 compliance not required)
	Loss per turn at minimum bend radius at 1550 nm	
10 mm	A1 ≤ 0.75 dB	
7.5 mm	A2 ≤ 0.5 dB	B2 ≤ 0.5 dB
5 mm		B3 ≤ 0.15 dB

Source: ITU-T G.657 Recommendation

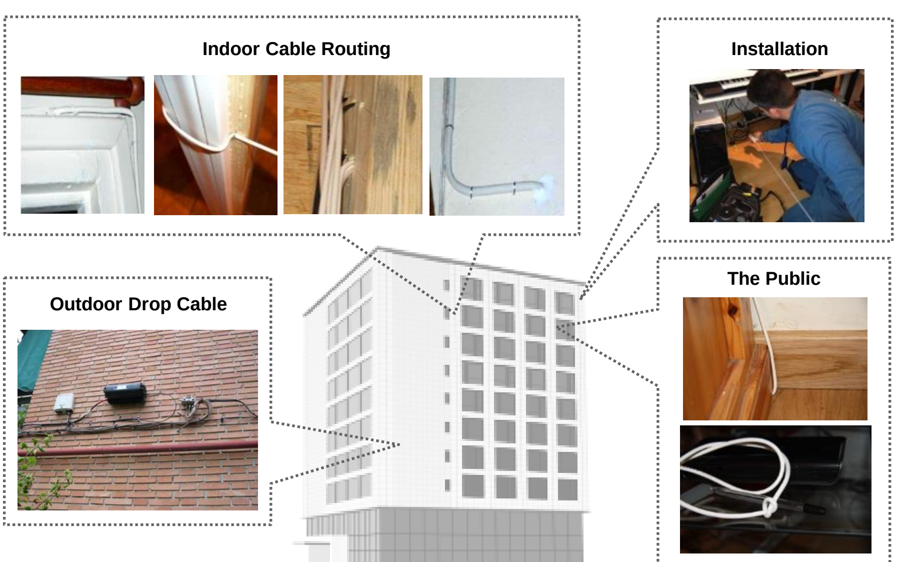
- The sub-categories specify different grades of performance depending on the severity of bending in the application and the requirement for backwards compatibility
- G.657.B3 products that achieve ultra-low bend loss whilst maintaining compliance with G.652.D are available in the market

Let’s Look at Each Part of the Network in Turn

The most important attributes change as you get closer to the home



Inside The Building There Are Lots of Places Where Tight Bends Can Be Introduced



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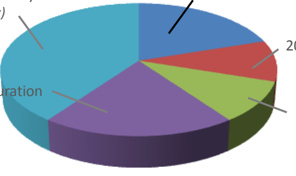
Bends are a Problem in the Construction of FTTH Networks

New Installation practices/requirements

- Higher installation speed requirements
- Must install "like copper" to enable lower installation labor cost
- Encounters more aggressive handling
- Increased chance of inappropriate installation procedures

Causes of errors in the construction of FTTH Networks*

Results from installing G.657.A1 and G.657.A2/B2 fibers in direct drop scenario



Source: Cablex presentation at Asut – Swiss Telecommunication Association www.asut.ch/files

Direct installer measurements demonstrates that FTTH installations problems are related to fiber bends accounting in some cases to 20%

Corning® ClearCurve® G.657 A2 and B3 Single-mode Fibers

- Corning offers a full portfolio of bend-enabled single-mode fibers
- Designed for lower cost and faster, more effective installations in FTTx applications
- Fully compliant with ITU-T G.652.D and applicable G.657 categories.

Corning® ClearCurve® ZBL fiber (G.657.B3)

Macrobend Loss

Mandrel Radius (mm)	Number of Turns	Wavelength (nm)	Induced Attenuation (dB)
5	1	1550	</= 0.10
5	1	1625	</= 0.30

Corning® ClearCurve® LBL fiber (G.657.A2)

Macrobend Loss

Mandrel Radius (mm)	Number of Turns	Wavelength (nm)	Induced Attenuation (dB)
7.5	1	1550	</= 0.4
7.5	1	1625	</= 0.8

Let's Look at Each Part of the Network in Turn

The most important attributes change as you get closer to the home

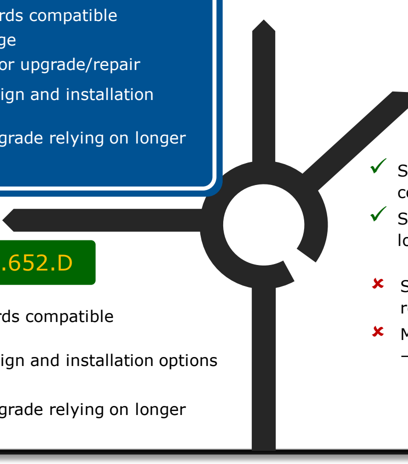
Outside Plant | **Indoors**

Bend Improved G.657.A1 fiber is sufficient for outside plant applications (ideally, augmented by low-loss)

Bend Insensitive G.657.A2/B3 fibers

Choosing the Right Fiber for Access Networks

Conflicting considerations



Low Loss G.652.D

- ✓ Highly backwards compatible
- ✓ Extend coverage
- ✓ Extra margin for upgrade/repair
- ✗ Limit cable design and installation options
- ✗ Unsuited to upgrade relying on longer wavelengths

G.657

- ✓ Supports smaller cables for low-cost installation
- ✓ Supports upgrade path relying on longer wavelengths
- ✗ Smaller Mode Field Diameter results in reduced compatibility
- ✗ Multiple grades of bend resistance – "how much is enough"

Traditional G.652.D

- ✓ Highly backwards compatible
- ✗ Limit cable design and installation options
- ✗ Limit coverage
- ✗ Unsuited to upgrade relying on longer wavelengths

G.657 Fibers Allows Design of Smaller Diameter Cables

- FTTH cables are frequently installed in crowded duct networks
- Improved bending resistance of G.657 fibers mitigates attenuation losses caused by designs with tight packing density designs

Increased space Utilization

Avoid additional trenching by fitting minicable and microducts into existing ducts

Smaller Hardware & Equipment

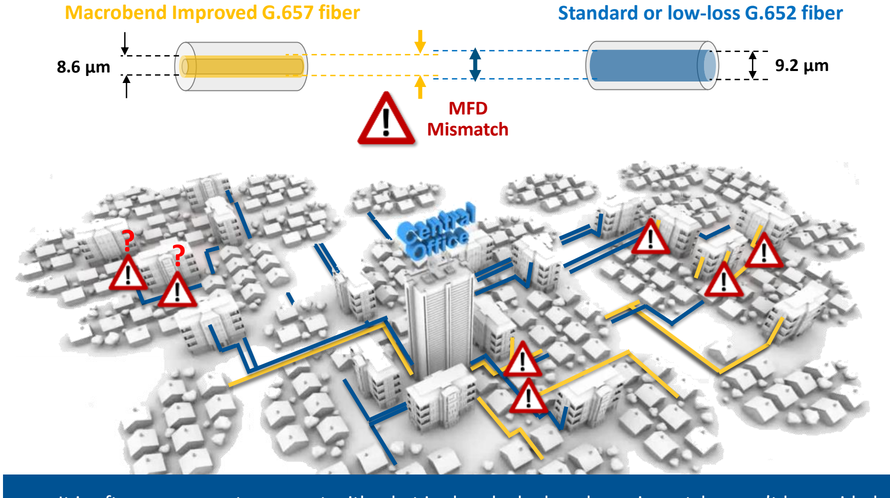
G.657 fibers can be more tightly coiled enabling smaller cabinets and closures

Reduced construction costs

By minimizing reworks due to loss at bends that occur during installation and maintenance

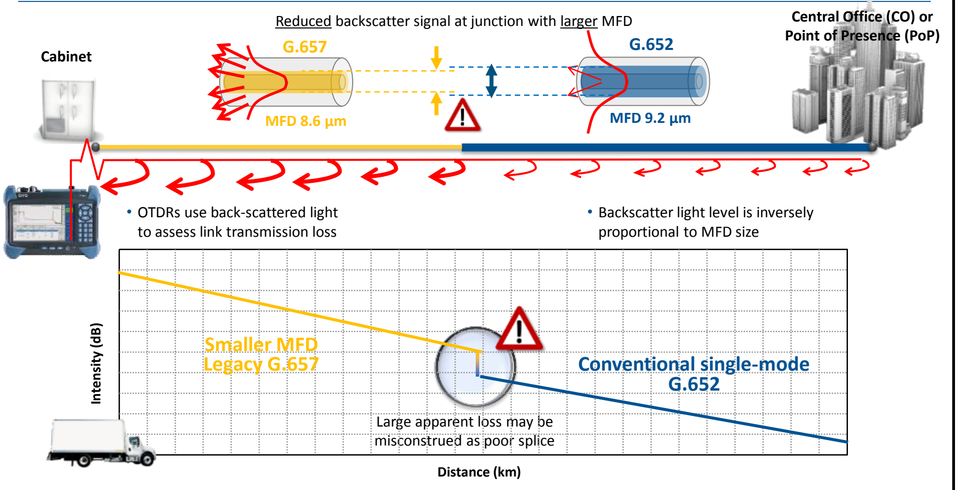
Bend improved fibers enable smaller diameter cables that reduce duct rental and construction costs, ease congestion and reduce installation time

But New Installations are Required to Connect Into Existing Infrastructure



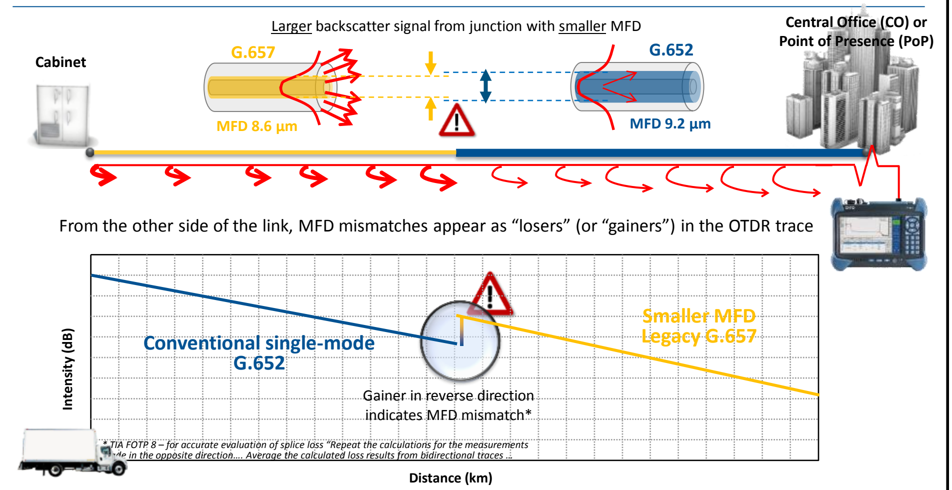
It is often necessary to connect with what is already deployed so mis-matches can't be avoided

Dissimilar Fiber Designs Can Hinder Splice Quality Testing



At the transition point from a G.657 fiber to a G.652 the difference in backscattered light will translate in the OTDR trace to a point of excessive loss (also known as a "loser")

Dissimilar Fiber Designs Can Hinder Splice Quality Testing



Operator needs to come to the other end of the link in which case the opposite effect translates to a "gainer" in the OTDR. The true splice loss is the average of the "gainer" and "loser

Corning SMF-28® Ultra Fiber

The first ITU G.652.D low attenuation, low macrobend loss and 9.2 µm MFD on the market

- SMF-28® Ultra fiber is the **first G.652.D fiber** to offer **macrobend** performance that exceeds the **G.657.A1 standard** along with **industry leading attenuation**
- But with a **9.2 µm MFD** equivalent to the majority of standard single-mode fibers **to allow for seamless integration into existing network**

Macrobend Loss

Mandrel Radius (mm)	Number of Turns	Wavelength (nm)	Induced Attenuation (dB)
10	1	1550	</= 0.50
10	1	1625	</= 1.5

Mode-Field Diameter

Wavelength (nm)	MFD (µm)
1310	9.2 ± 0.4
1550	10.4 ± 0.5

Maximum Attenuation

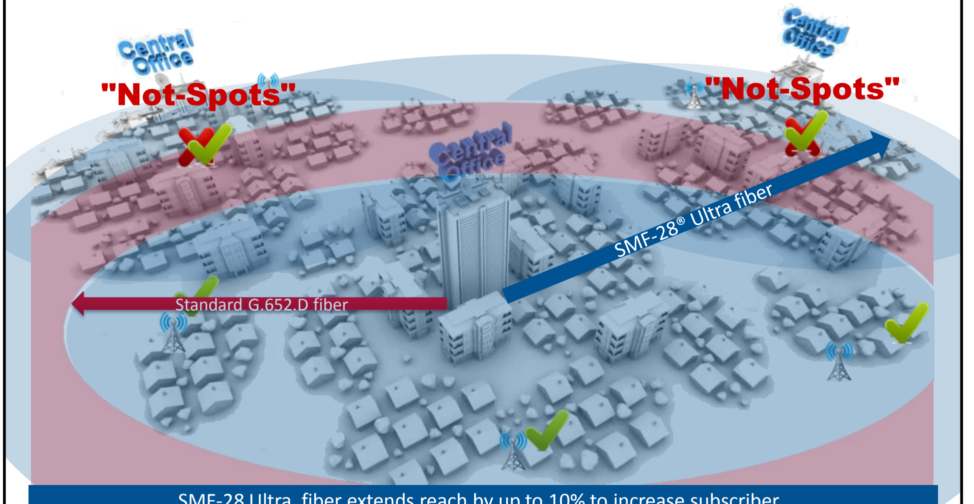
Wavelength (nm)	Maximum Value (dB/km)
1310	≤ 0.32
1383±3	≤ 0.32
1490	≤ 0.21
1550	≤ 0.18
1625	≤ 0.20

Polarization Mode Dispersion (PMD)

	Value (ps/√km)
PMD Link Design Value	≤ 0.04
Maximum Individual Fiber PMD	≤ 0.1

Low loss SMF-28® Ultra delivers extended FTTH reach

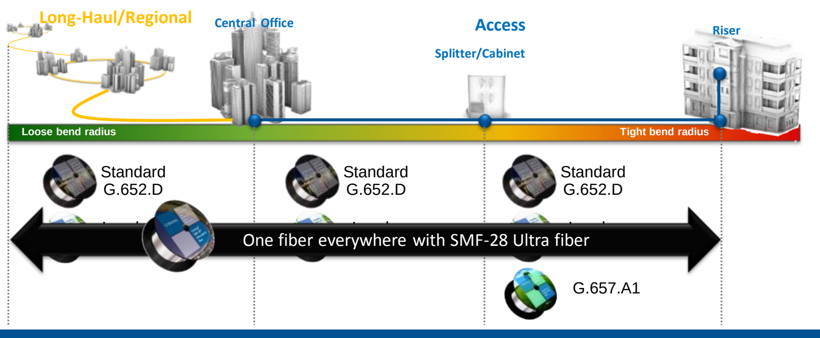
Particularly important for longer, more rural Installations



SMF-28 Ultra fiber extends reach by up to 10% to increase subscriber coverage area by up to 20% and facilitate central office consolidation

One Fiber Everywhere for Minimal Network Complexity

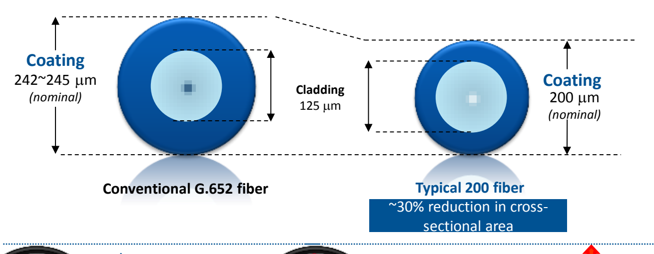
- Requirements for use of different fibers in different parts of the network can lead to compatibility issues and inventory management complexity
- Low Loss of SMF-28 Ultra enables longer spans and reach in LH networks
- Larger MFD of SMF-28 Ultra also adds value for use in LH (where WDM leads to high power in core)

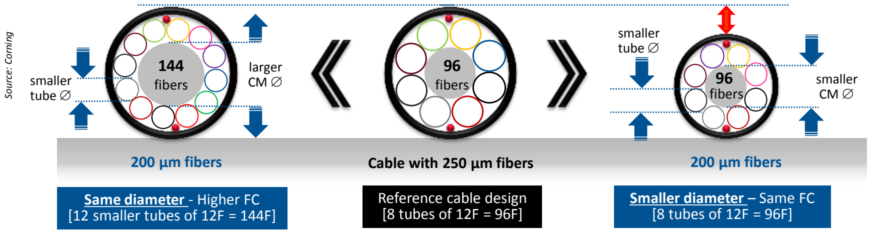


Minimize network complexity by using one fiber everywhere
…that gives you both low loss + improved bend
Corning® SMF-28® Ultra fiber is a key enabler for operators to reduce network complexity/costs

200 Micron Diameter Fibers Enable Higher Fiber Density

- 200 um fibers retain the 125 µm glass cladding diameter of conventional fibers but feature smaller diameter coating to allow for further cable miniaturization



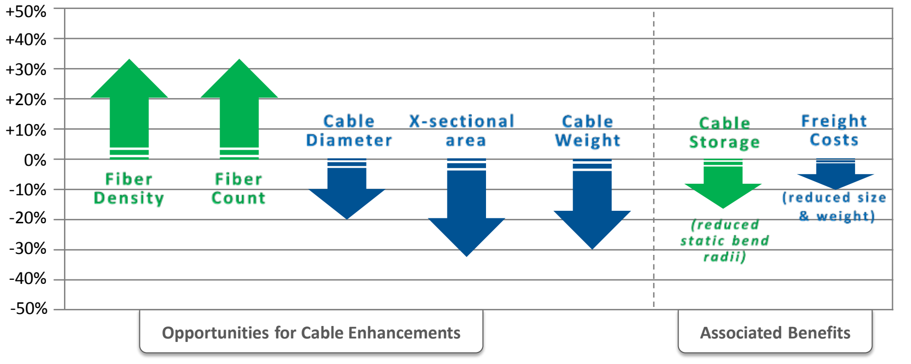


Why Space Matters

Potential cable benefits of utilising 200 µm fibers

Cable properties & associated benefits of 200 µm vs. 242 µm fibers

(Estimation based on 96FC duct cable)

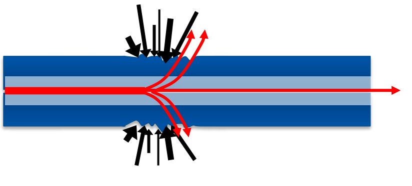


Alongside higher fiber density in the cable, 200 micron fibers offer practical benefits that help make optical fiber easier to deploy deeper into the network in areas where space is at a premium

The Microbending Problem in 200 um Fibers

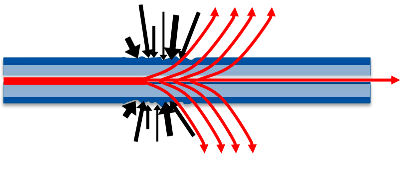
- Reduced coating thickness could lead to more microbend loss in the fibre through diminished resistance to external stress

Conventional 242 um coating fiber



- External stresses can be transmitted through the coating leading to perturbations of the optical core and light escaping from fiber

200 um coating fiber



- The same forces on a fiber with a thinner coating leads to much greater microbending loss

ITU-T G.657 Compliant Glass Design Protects 200 µm Fibers From The Effects of Macro and Microbending

Macrobending

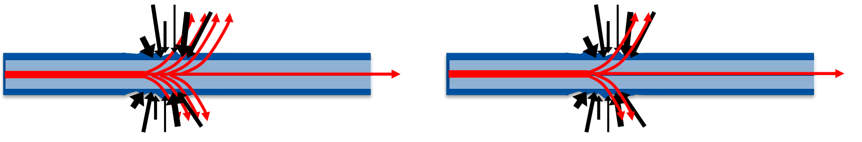
- G.657 fibers are popular for their improved macrobend performance that prevents the optical signal from leaking out of the fiber when this is bent

G.652 standard fiber **G.657 fiber**

Microbending

- The G.657 design also provides protection against microbending

G.652 standard fiber + 200 µm coating **G.657 fiber + 200 µm coating**

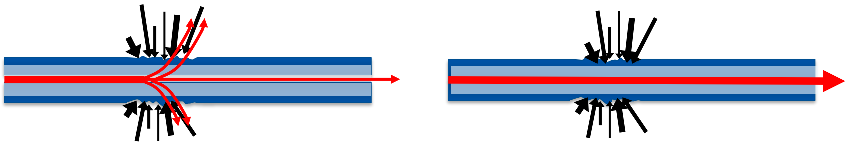


The improved microbending performance of G.657 fibers enables 200um fiber to operate without excessive microbending loss

Advanced Coating Designs Also Protect 200 µm Fiber From Microbending Loss

- In addition to G.657 glass design, light can be protected from microbending effects by advanced coating materials that absorb external forces , rather than transmit them to the glass

200 µm fiber with conventional coating **200 µm fiber with advanced coating**



The combination of G.657 glass and advanced coating provides sufficient microbending protection to allow high density fiber packing in cables

Corning® ClearCurve® 200 fiber (G.657.A1)

Single-mode optical fiber with space saving 200 µm diameter coating

- Same glass design as Corning's ClearCurve® XB fiber: millions of kms sold worldwide
- Superior CPC® fiber coating system optimized for cable miniaturization and fiber processability
- Enables smaller and lighter-weight cables which can improve duct utilization, enable smaller enclosures or reduce the weight of aerial deployments

Macrobend Loss

Mandrel Radius (mm)	Number of Turns	Wavelength (nm)	Induced Attenuation (dB)
10	1	1550	</= 0.50
10	1	1625	</= 1.5

Geometrical Parameters

Parameter	Units	Specification
Coating Diameter	Microns	200 ± 10
Cladding Diameter	Microns	125.0 ± 0.7
Cladding Non-Circularity	%	≤ 0.7
Core-Clad Concentricity	Microns	≤ 0.5

Maximum Attenuation

Wavelength (nm)	Maximum Value (dB/km)
1310	0.33 - 0.35
1383±3	0.31 - 0.35
1490	0.21 - 0.24
1550	0.19 - 0.20
1625	0.20 - 0.23

Mode-Field Diameter

Wavelength (nm)	MFD (µm)
1310	8.6 ± 0.4
1550	9.8 ± 0.5

Duct Evolution

- Increasing fiber capacity within existing duct infrastructure footprint enabled by 200 µm fibers leads to more flexible and future-proofed access networks

Total Capacity: 2 x 96FC	Total Capacity: 3 x 96FC	Total Capacity: 4 x 96FC
Microduct : 14/12 (diameter / bore)	Microduct : 12/10 (diameter / bore)	Microduct : 10/8 (diameter / bore)

- Reutilization of duct infrastructure avoids CapEx of additional trench digging and duct laying: open trenching techniques can be expensive particularly in urban areas with prices varying from $110-$190 per metre*

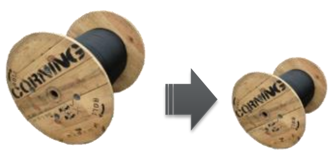
The higher fiber density enabled by 200 µm fiber improves duct utilization reducing infrastructure construction costs

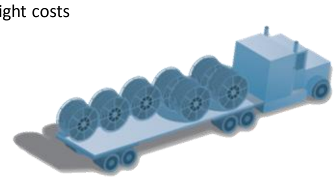
**Source: UK Department of Culture, Media and Sports (2011)*

Easier Transport, Handleability and Installation

- Smaller and lighter weight cables enabled by 200 µm fibers offer practical benefits that help make optical fiber easier to transport, handle and deploy
  - **Easier cable handling:** enable faster deployment speeds
  - **Longer blowing distance:** extended blowing distances can be achieved, reducing installation time and supporting more flexible and agile cost-effective installations

  - **Smaller and lighter reels:** for easy transport and Lower freight costs





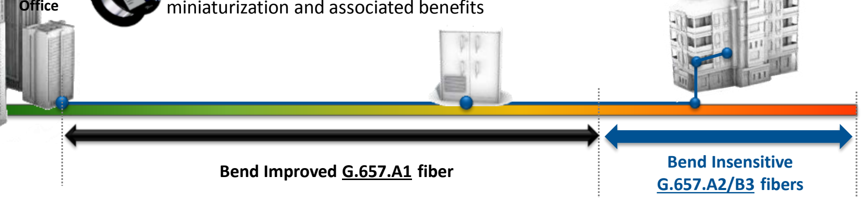
Macrobend Improved Fibers Are a Key Enabler of Access Networks

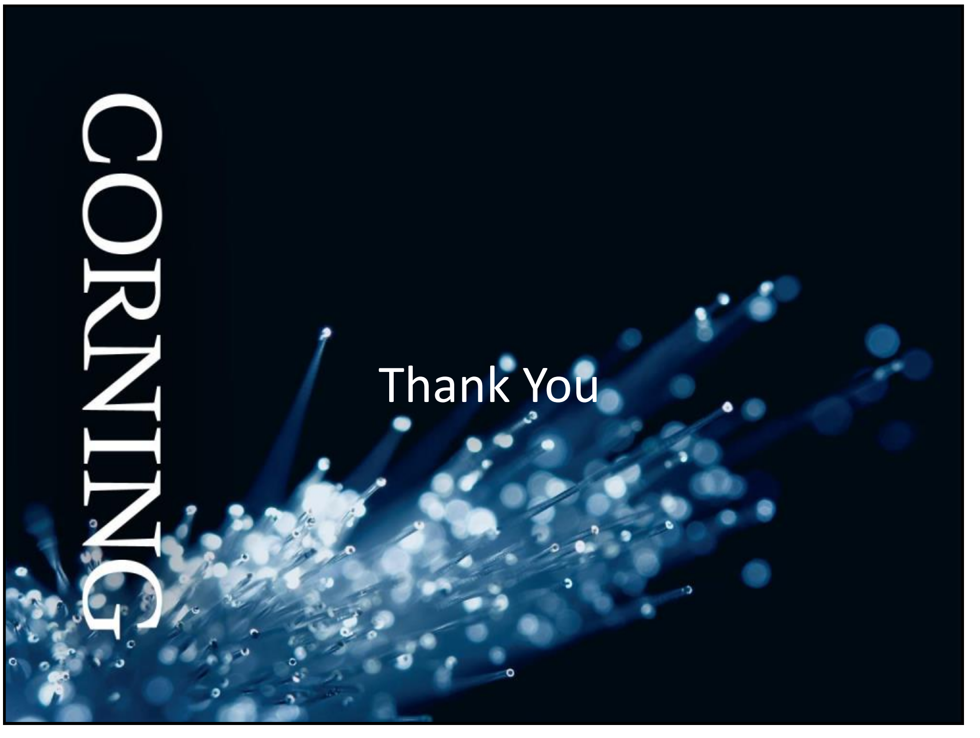
Outside Plant	Indoors
• Macrobend improved G.657.A1 fibers allow for: • Smaller hardware and equipment • Smaller and lighter advanced cable designs • Increased space utilization • Reduced construction costs	• Macrobend insensitive G.657.B3 and G.657.A2 fibers enable lower cost and faster, more effective installations in FTTx applications

SMF-28® Ultra fiber with **9.2 µm** Mode Field Diameter for seamless integration into existing network

ClearCurve® 200 fiber for further miniaturization and associated benefits

ClearCurve® ZBL or ClearCurve® LBL fiber

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Thank You