Bend-Optimized Fiber in FTTx Applications

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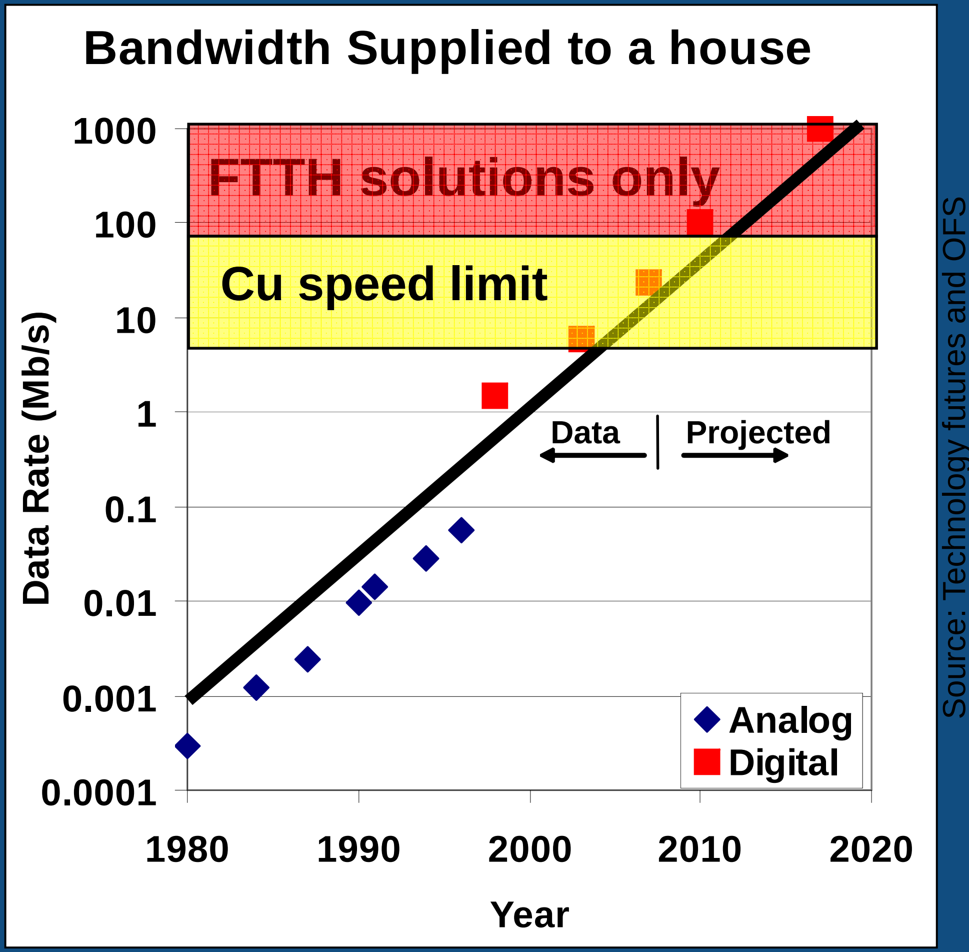
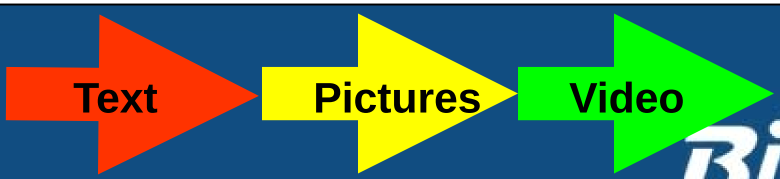
Growth in Bandwidth Demand

42% annual growth rate in bandwidth

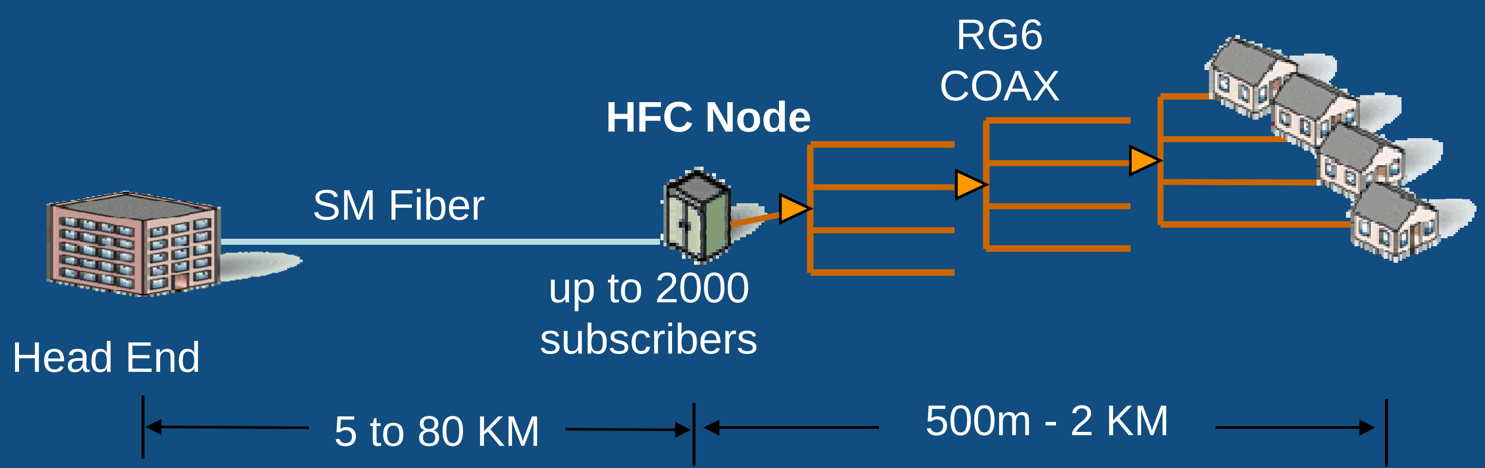
Largest Bandwidth users:

- **Video on demand**
- **HDTV**
- **Internet video**





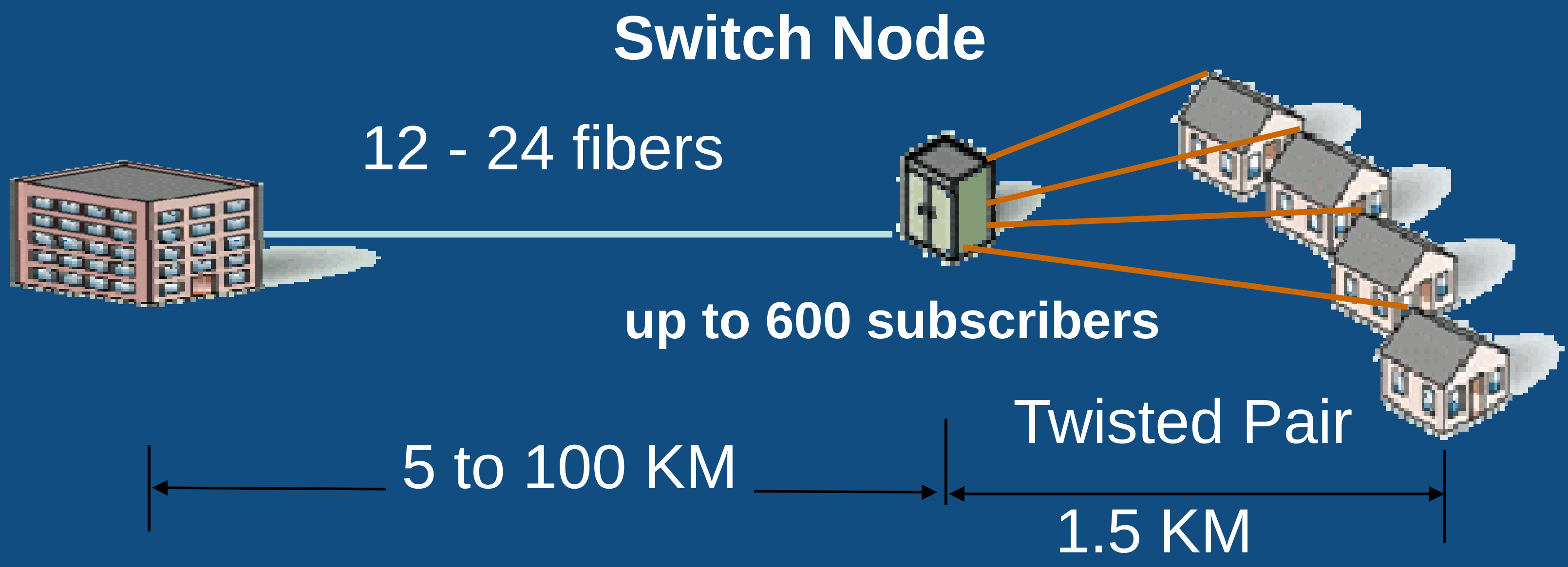
FTTx Examples
HFC – Hybrid Fiber COAX



5 – 10 Mb/s typical downstream, upstream 0.1 to 1 Mb/ today

Higher bandwidths possible with fewer subscribers

FTTx Examples
FTTN - Fiber to the node



Potential 24 Mbps

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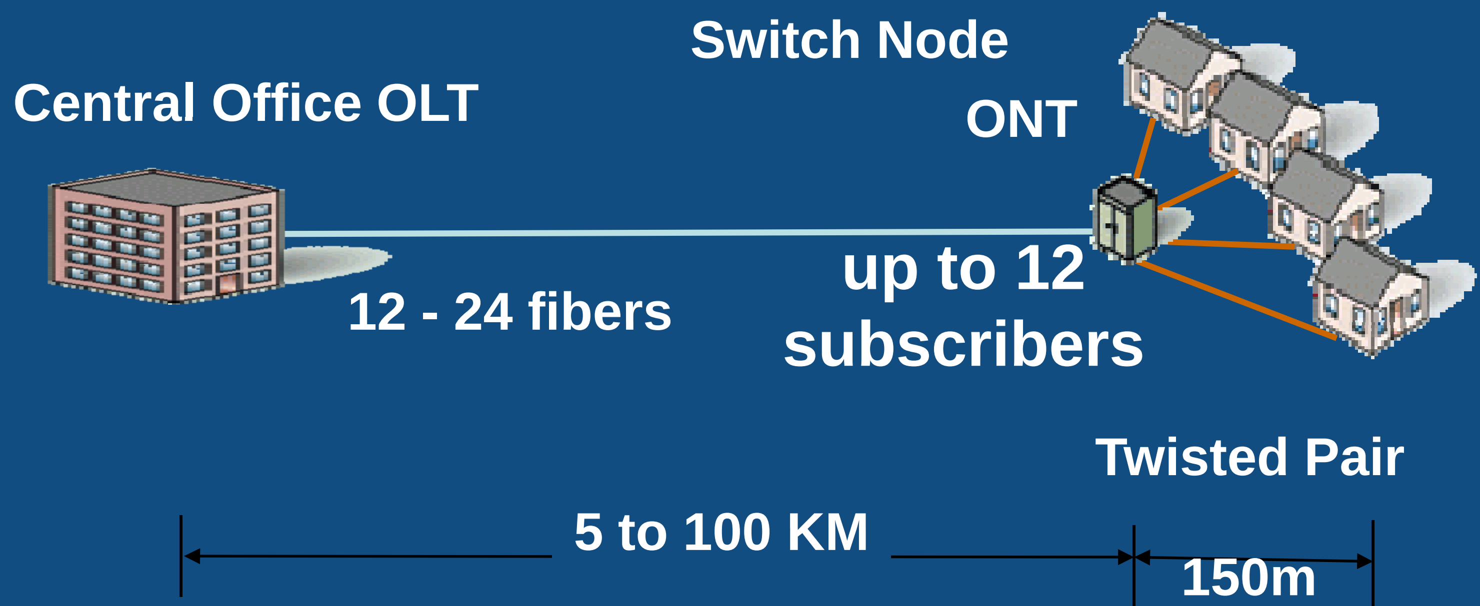
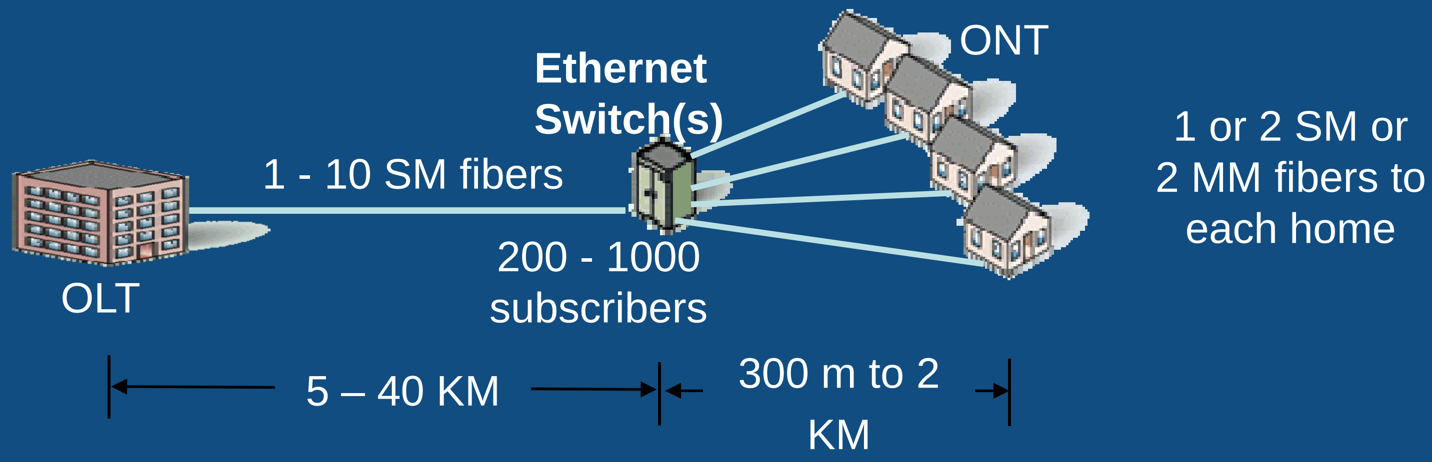
FTTx Examples
FTTC – Fiber to the Curb



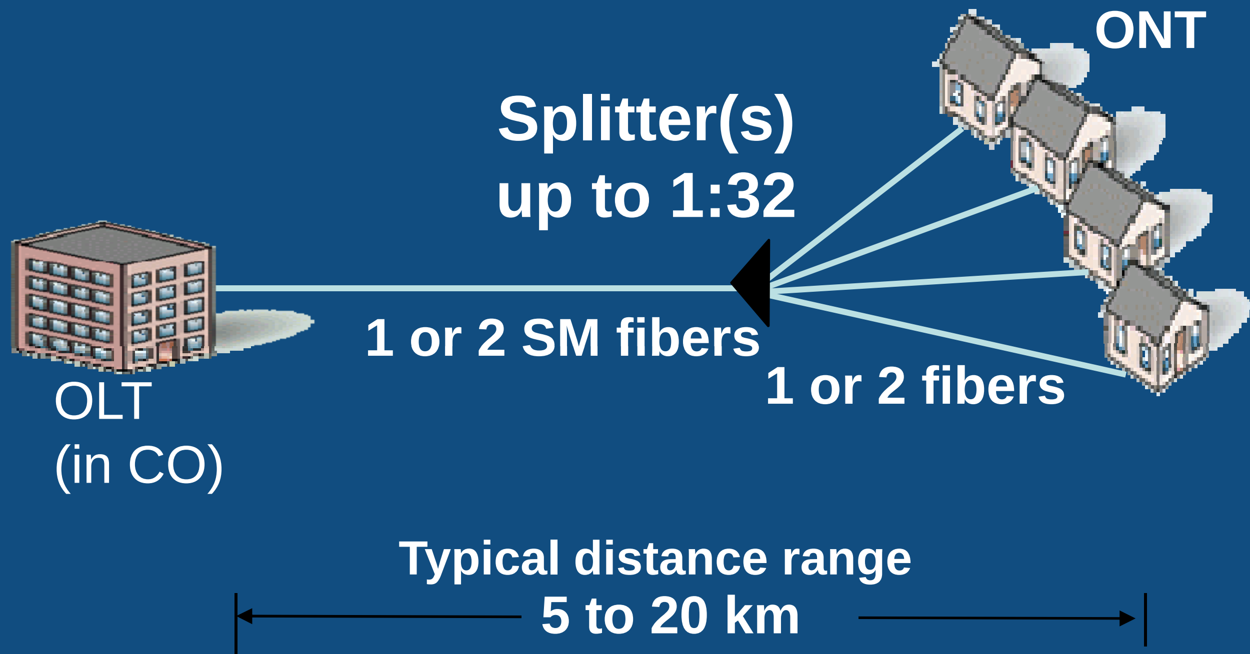
Potential 100 Mbps

FTTx Examples
FTTH – Fiber to the Home
Ethernet Switched Optical Network (ESON)



Current 10-100 Mb/s per subscriber
Potential 10 Gb/s per subscriber

FTTx Examples
FTTH – Fiber to the Home
Passive optical network (PON)



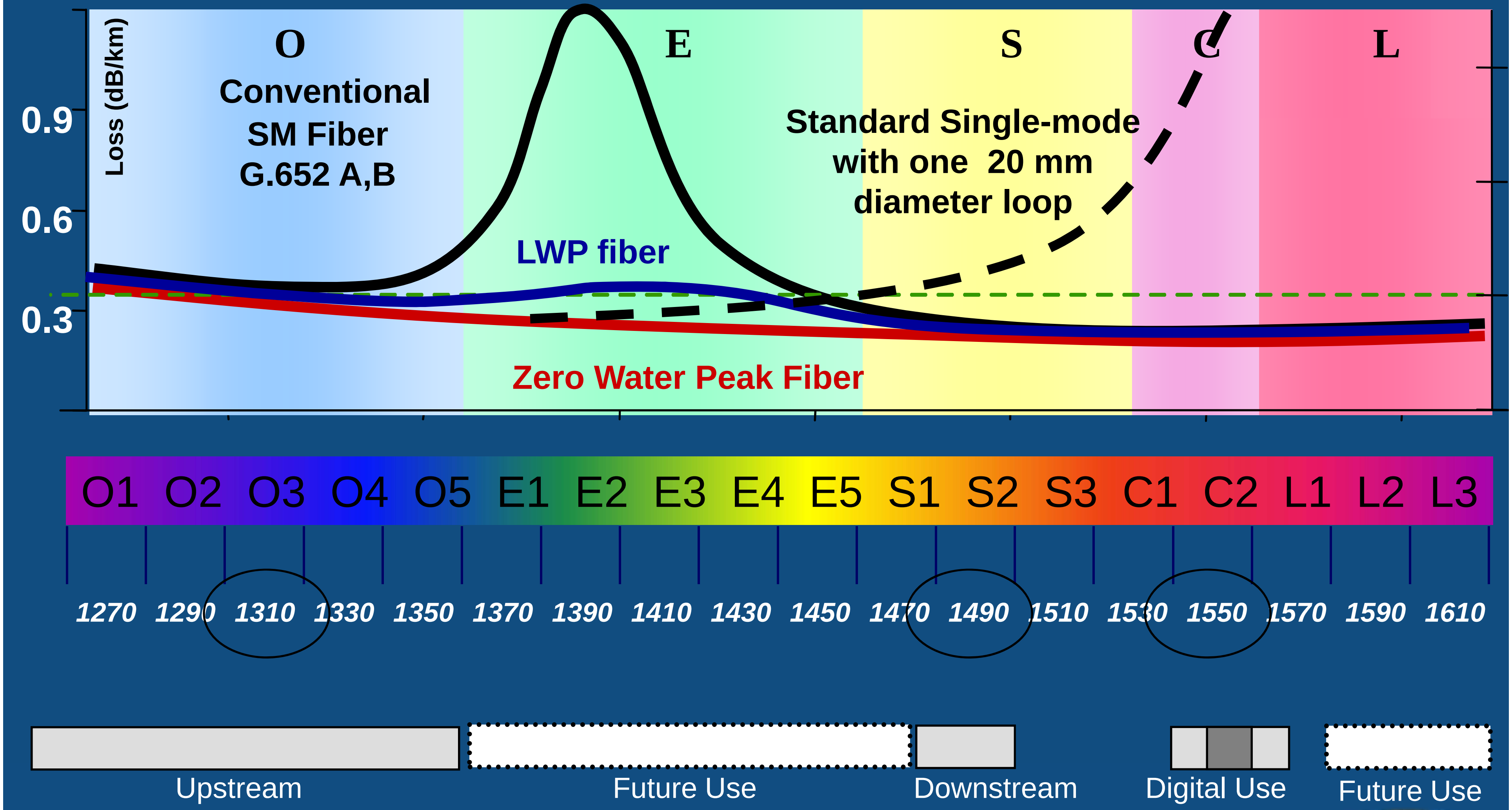
Current 20 – 1000 Mb/s

Potential 10 Gb/s per subscriber

What is being deployed

Network Type and Supported Application	Standard(s)	Video Wavelength(s) on each fiber
FTTH – PON	ITU-T G.983 (BPON)	1490 nm downstream **and 1310 nm upstream**
	ITU-T G.984 (GPON)	
	IEEE 802.3ah (GE-PON) 1000BASE-PX	
FTTH – Active Ethernet **FTTC – Feeder to Curb** **FTTN - Feeder to Node** **Enterprise**	IEEE 802.3 Ethernet 100BASE-BX	1550 nm downstream **and 1310 nm upstream**
	IEEE 802.3 Ethernet 1000BASE-BX	1490 nm downstream **and 1310 nm upstream**
FTTH PON or HFC Broadcast RF Video	SCTE and ITU	1550 – 1560 nm
10GEPON and 10GPON	IEEE 802.3 study group ITU Study Group	**TBD – likely to include wavelengths** > 1490 nm.
DWDM PON	Future standards and/or multiple PONs on single ODN	1480 – 1625 nm
CWDM PON		**1260 –** 1625 nm

Value of Full Spectrum fiber

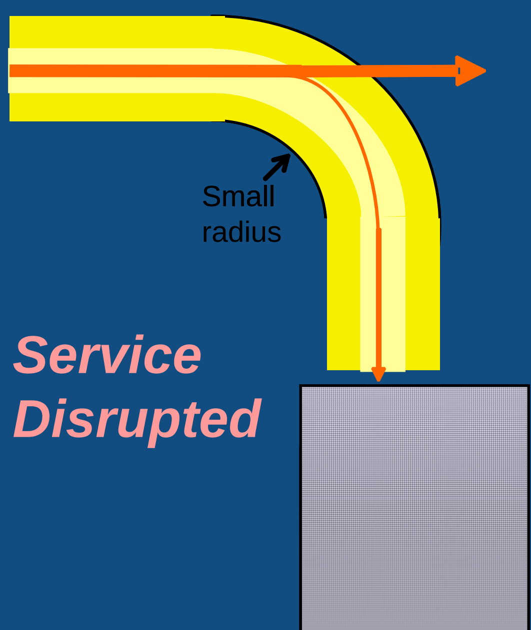


Macrobend Simplified

When does a fiber scream

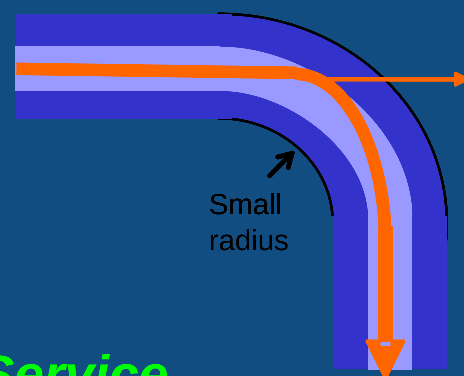
"I don't like what you are doing!"

Conventional Singlemode fiber



Service Disrupted

Bending Optimized Singlemode fiber



Service Maintained

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Macrobend Simplified
Minimum designed bend

Conventional Singlemode fiber
- 15 mm radius

G.657 A Singlemode Fiber
- 10 mm radius

G.657 B Singlemode Fiber
- 7.5 mm radius

Non-standard Singlemode fiber
- 5 mm radius

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What is in the standards

- ITU G.657 standard describes fibers with improved macrobend performance. The standard describes two classes of fibers
  - Class A- Fully compliant with G.652.D with improved bending performance. The minimum designed bend radius is 10 mm.
  - Class B- Fiber designs for niche indoor wiring projects with very low macro bend loss not required to be compliant with G.652 standard. The minimum designed bend radius is 7.5 mm.

Macro-bend Performance Table

ITU Std	Bend Radius (mm)	# of Turns	Wave-length	ITU Std (dB) Max.
G . 6 5 7 A	10	1	1550 nm	0.75
			1625 nm	1.5
	15	10	1550 nm	0.25
			1625 nm	1.0
G.657 B	7.5	1	1550 nm	0.5
			1625 nm	1.0
	10	1	1550 nm	0.1
			1625 nm	0.2
	15	10	1550 nm	0.03
			1625 nm	0.1

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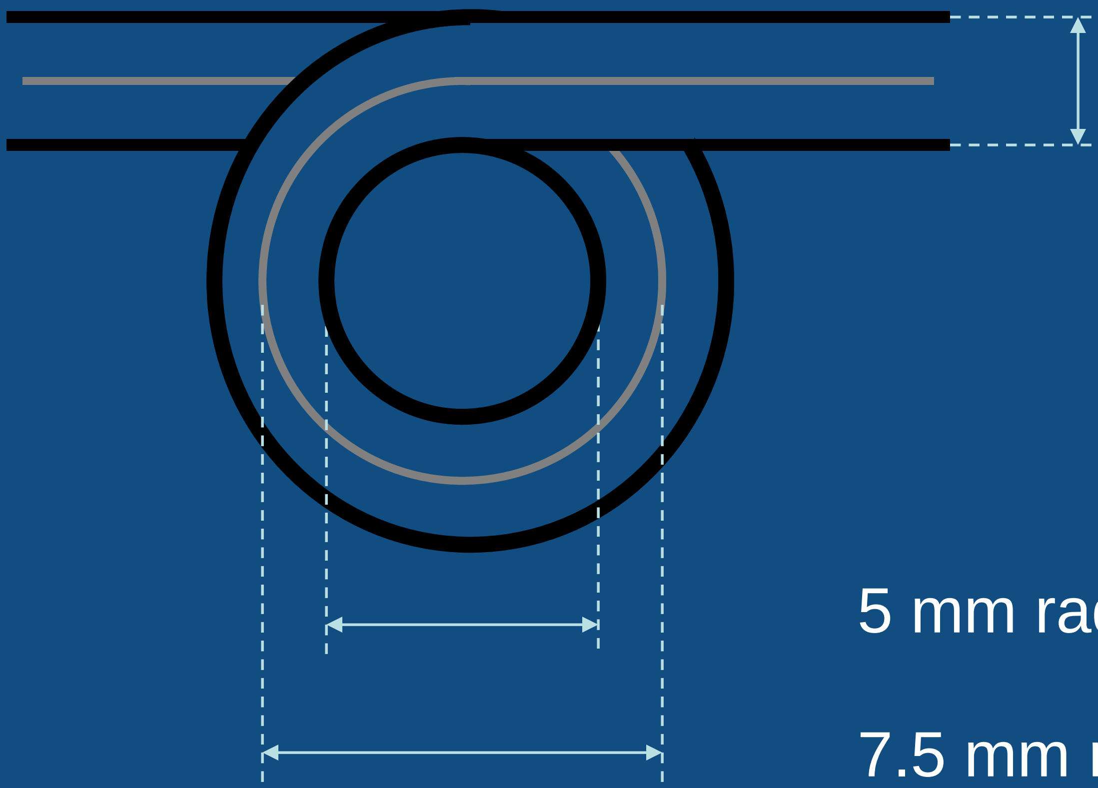
What is being specified/tested



5 mm optical cable

5 mm radius mandrel

7.5 mm macrobend in optical fiber

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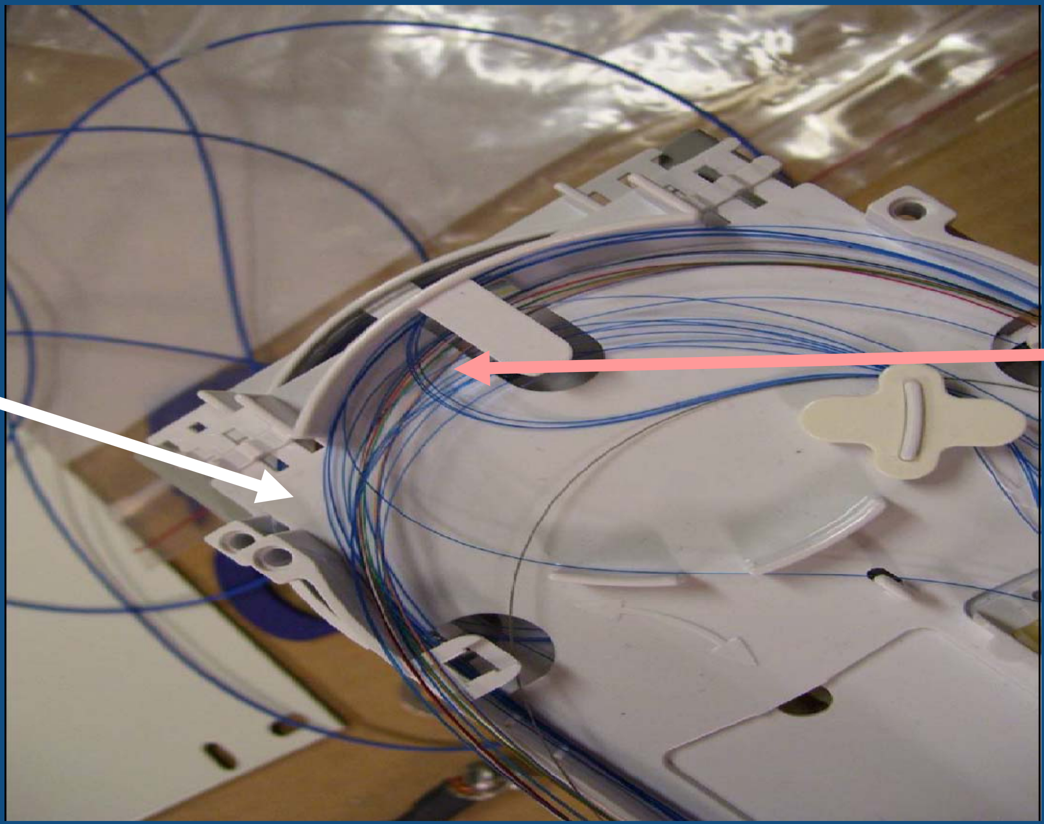
Why do you need G.657 Class A fiber?
In OSP connectivity reality rarely meets theory

Theory



Reality

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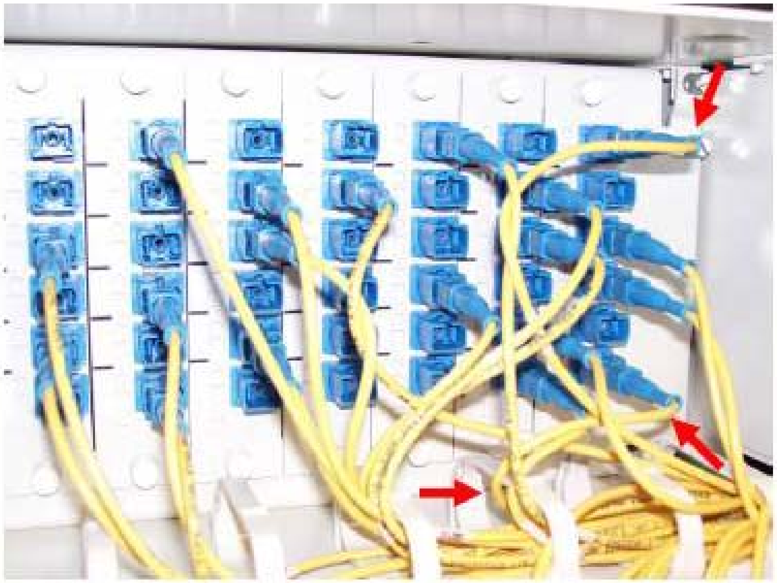
Why do you need G.657 Class A or B fiber compliant with the installed base?

Theory

Reality



Fiber Distribution Cabinet Patching for PON or Point to Point System

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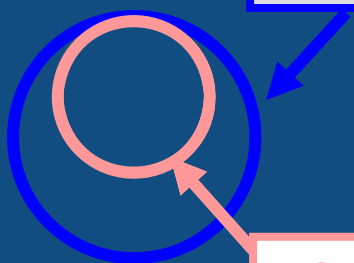
Why do you need G.657 Class A or B fiber compliant with the installed base for connectivity?

16mm Min. Radius:

G.652.D Bare Fiber



10mm Min. Radius:

G.657.A Bare Fiber

Smaller Splitter Cabinet:

144f in 20” x 18 ½” x 10”

Smaller apparatus is enabled by using bend improved singlemode fibers to reduce the size of splitters and connectivity

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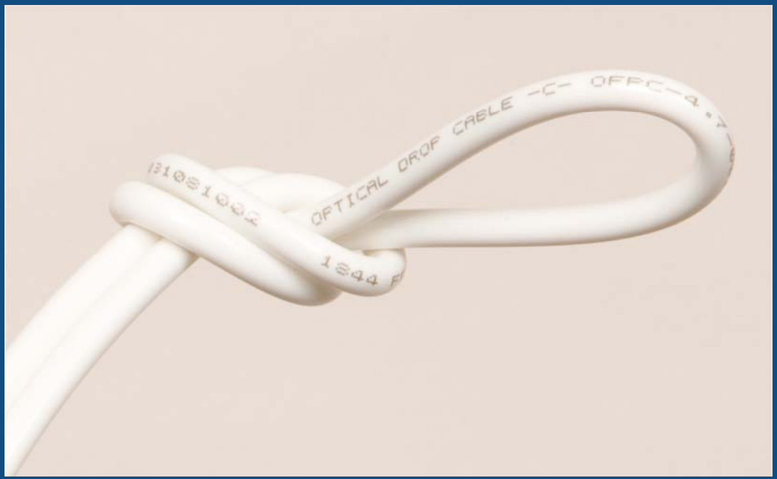
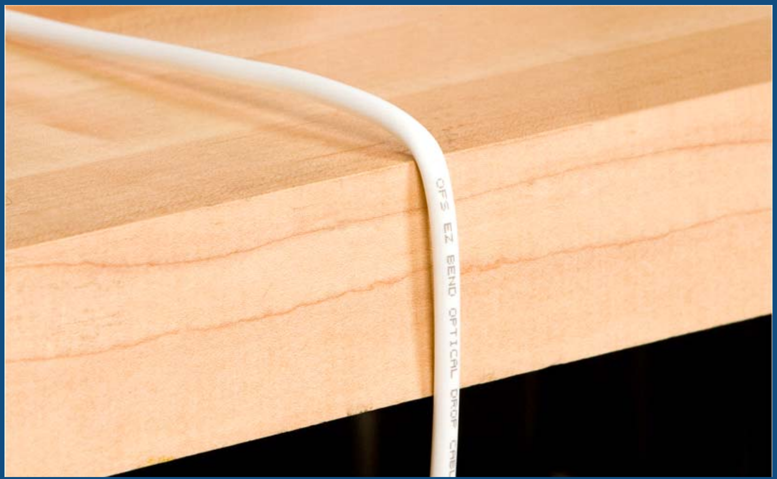
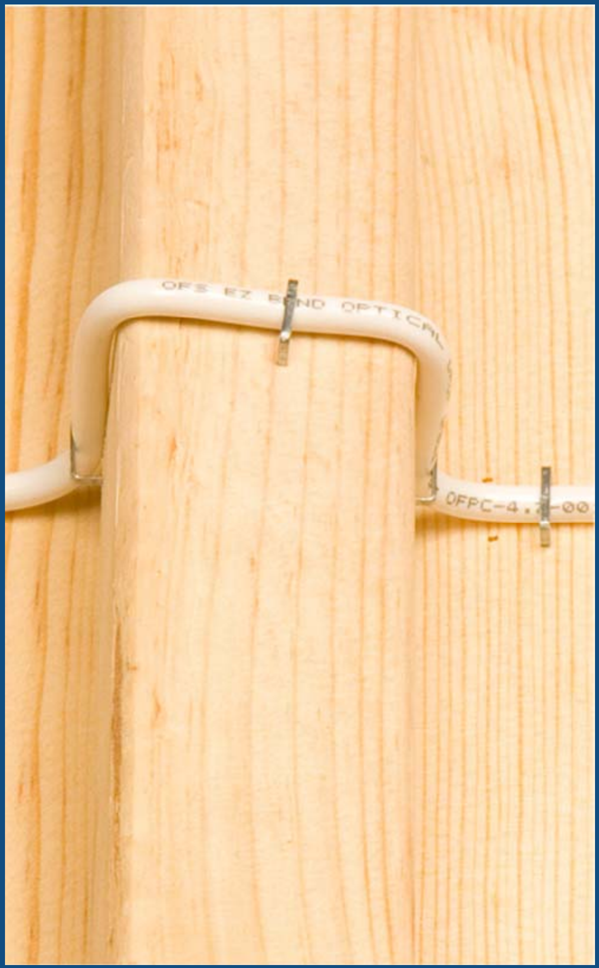
Why is G.657 class B fiber required for in building applications?

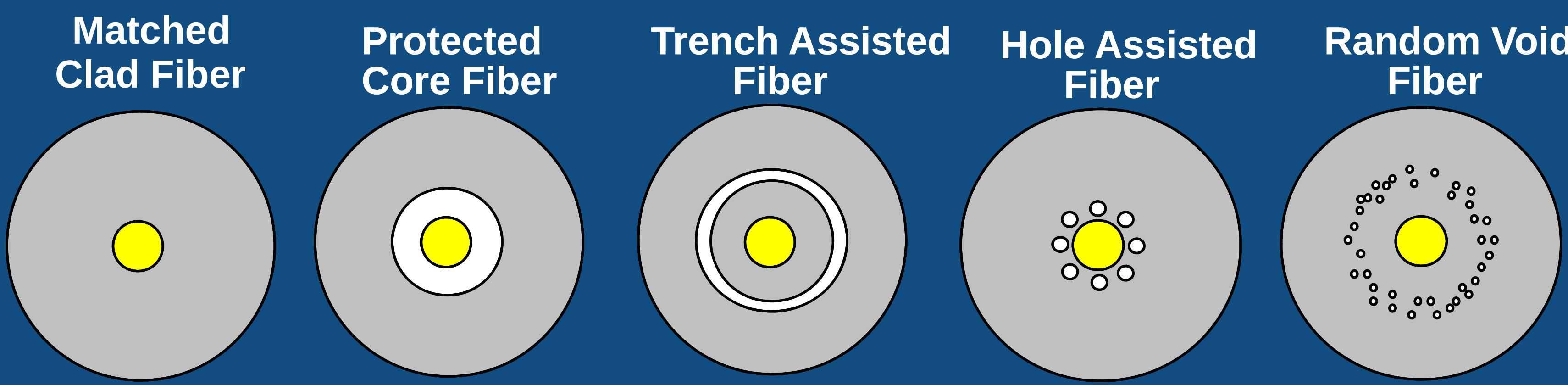
When G.657 Class B performance is not enough …







Singlemode fiber designs with improved bend performance



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Fusion Splice Compatibility table

Clad/Core aligned splice equipment	Matched Clad	Protected core fiber	Trench assisted fiber	Hole assisted Fiber	Random Void fiber
Matched Clad	YES/YES	YES/YES	YES/NO	NO/NO	YES/NO
Protected core	YES/YES	YES/YES	YES/NO	NO/NO	?

YES indicates fiber splices with standard recipe and procedures

NO indicates special splice recipes and/or procedures may be required

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Next Generation Singlemode Fiber: Targeted at MDU FTTH

Current state of the art for minimum designed bend radius:

•*ITU G.657A (10 mm)*
•*ITU G.657B (7.5 mm)*

However …

significant improvements in bend performance are needed for MDU FTTH Overbuilds & In-Home Wiring

•*MDU applications (5 mm)*

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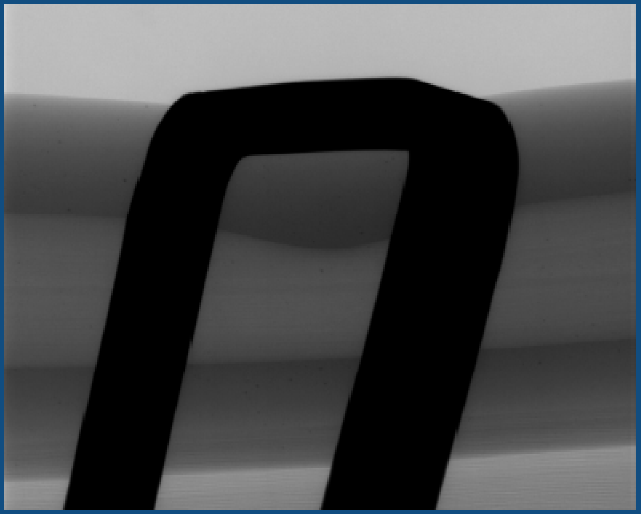
Stapling Optical Cables

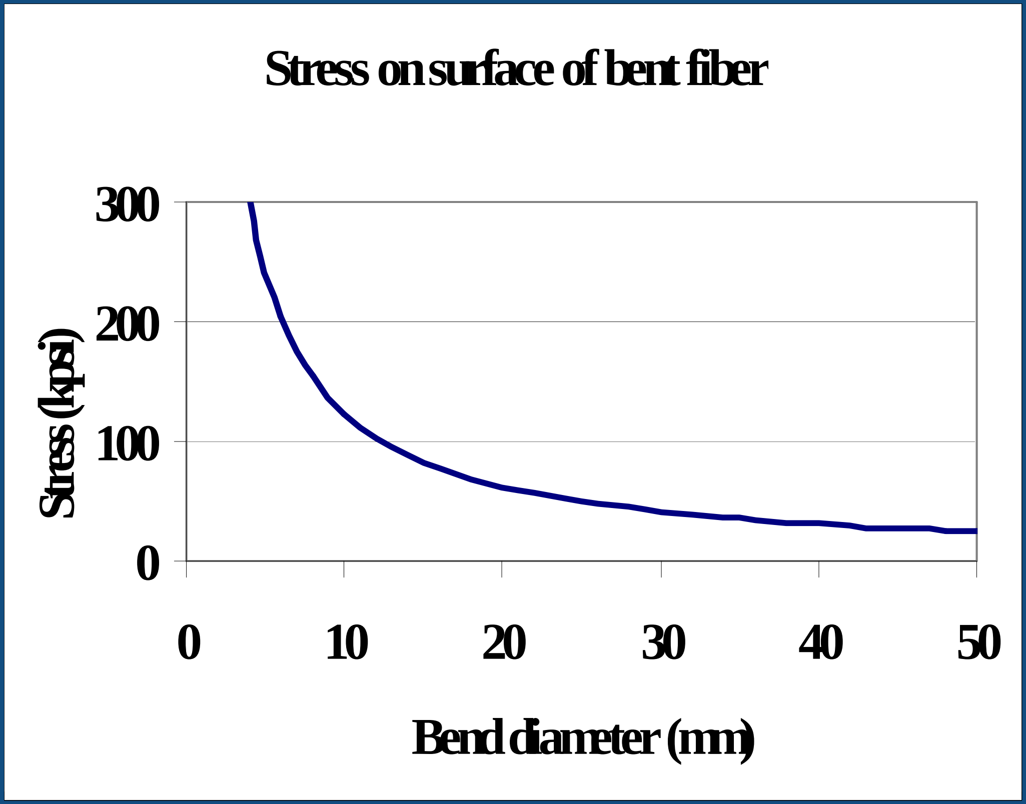
Staples produce variable forces and bends in the optical fibers after stapling. Optical cables used in this environment must protect the optical fiber from these forces

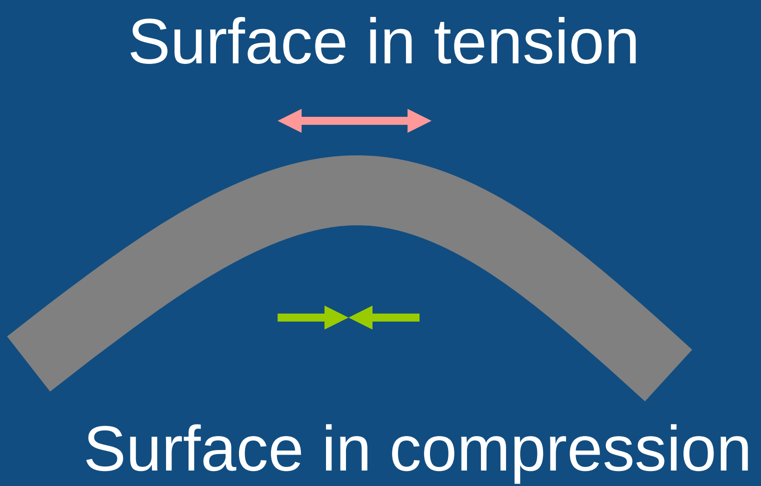
X-Ray image



X-ray of optical cable in bend

Why does bending a fiber impact mechanical performance?

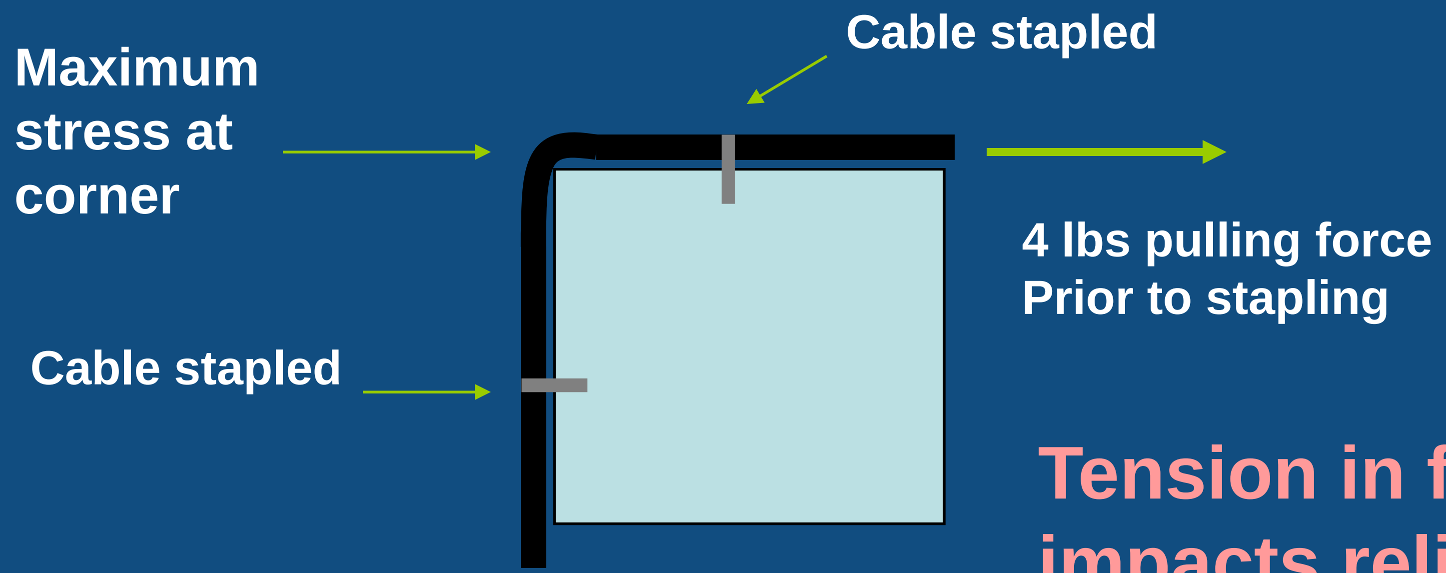




Reliability in sharp bends

single ¼ turn calculation

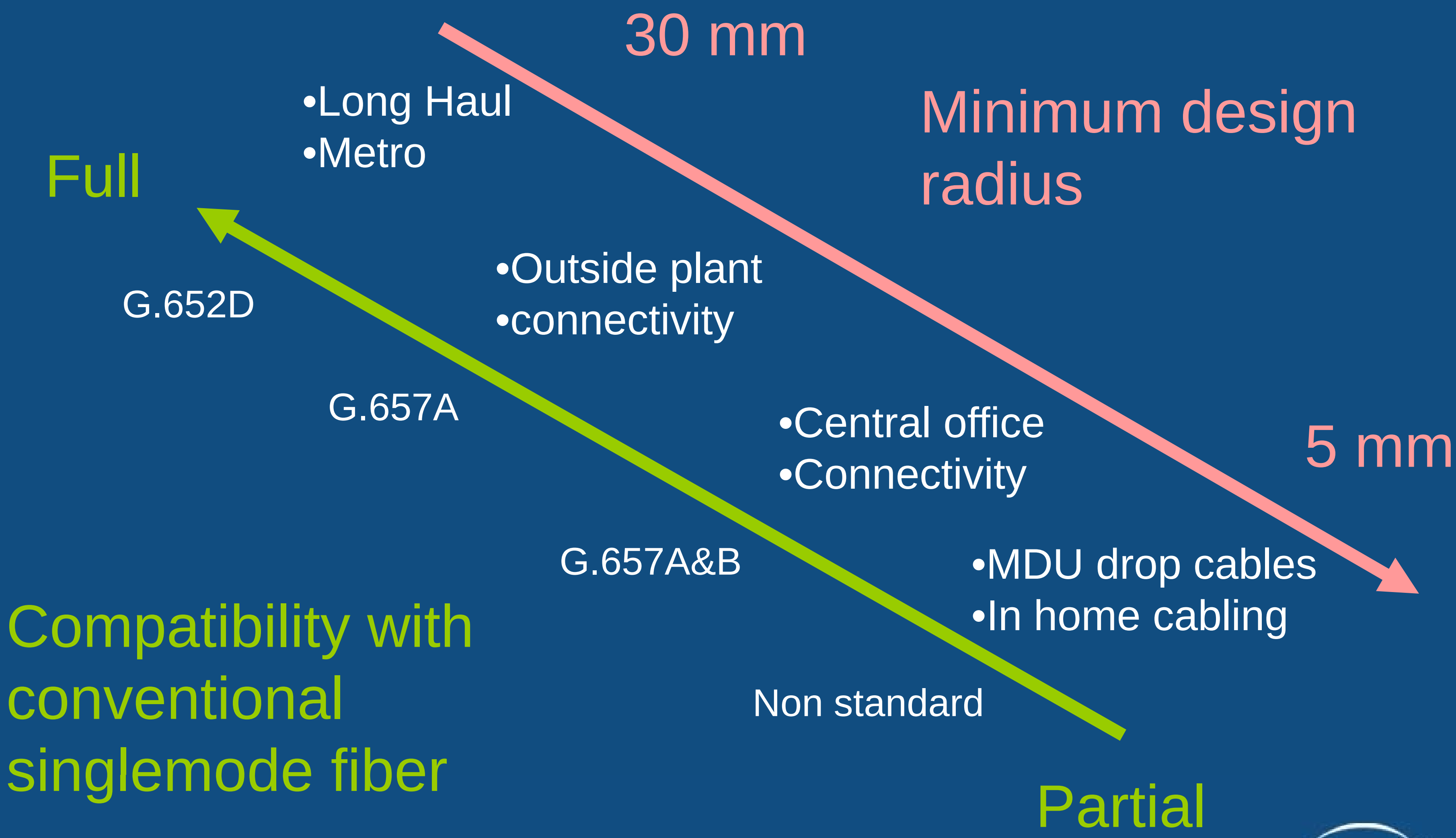
Cable bend radius	Pull force (pounds force)	Fiber strain kpsi	20 year failure probability
5 mm	0	~100	< 1 ppm
5 mm	4	~300	> 50%



Cable is 4.7 mm diameter and limits fiber bend diameter

Tension in fibers impacts reliability!

Meeting the Bending Challenges



Summary

- There are a lot of applications for optical fibers with improved bend performance
- Bending properties for optical fibers should match the application requirements
- Bend-optimized optical fibers have improved macrobend performance but mechanical characteristics of glass have not changed

Thank You!

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