Is transforming multimode fibers into singlemode fibers possible ?

How to use innovative optical technology to upgrade aging cabling infrastructure ?

cailabs
SHAPING THE LIGHT

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Product Line Manager, Cailabs

BICSI Mainland Europe – Milan – 08 November 2018

BICSI

Outline

- Increased capacity needs in Local Area Networks
- Modal dispersion is limiting capacity on multimode fibers
- How to overcome this issue?
- Multi-Plane Light Conversion (MPLC) technology
- Multimode fiber plant upgrade use cases

Increased bandwidth capacity needs

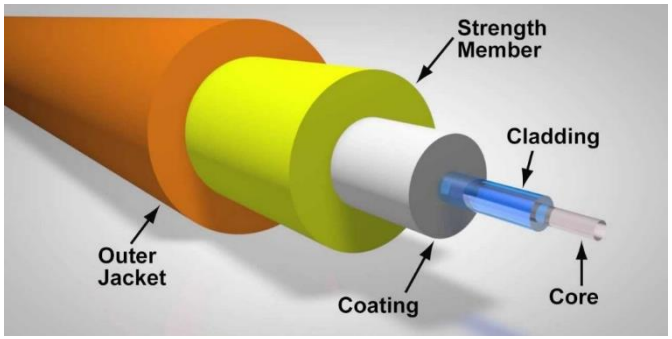
- WiFi – Distributed Antenna Systems
- VoIP, video-conférence
- CCTV (video surveillance)
- Shared storage
- Professionnal software & apps
- Real time apps
- Virtualization, cloud computing
- Connected objects, BYOD, IoT
- Smart building, …

Bandwidth-intensive applications + latency-aware traffic types

- **LAN cabling infrastructures need to support ever growing bit rates**

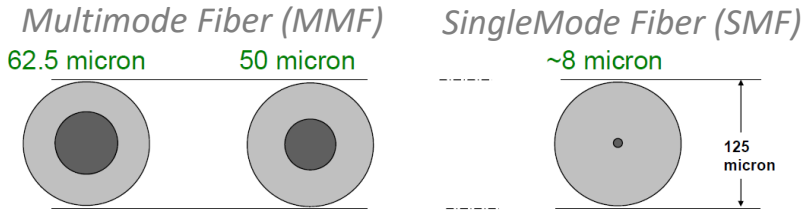
Optical fiber reminder

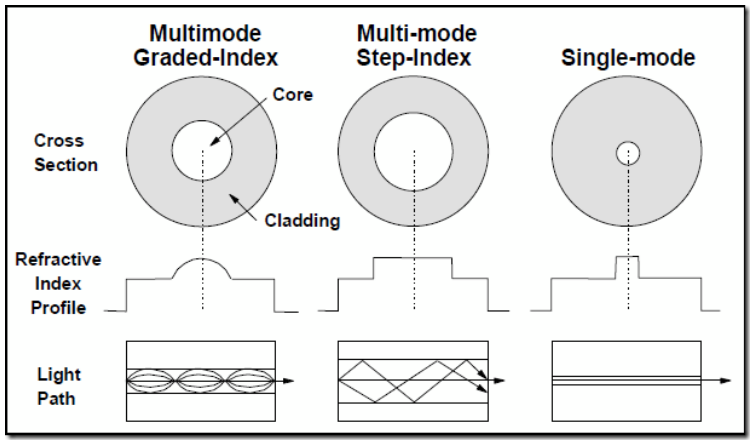
Low linear loss, low footprint, EM insensitivity



Differentiation of optical fibers according to :

- **Geometrical properties**
- **Index profile** (graded index or step index)



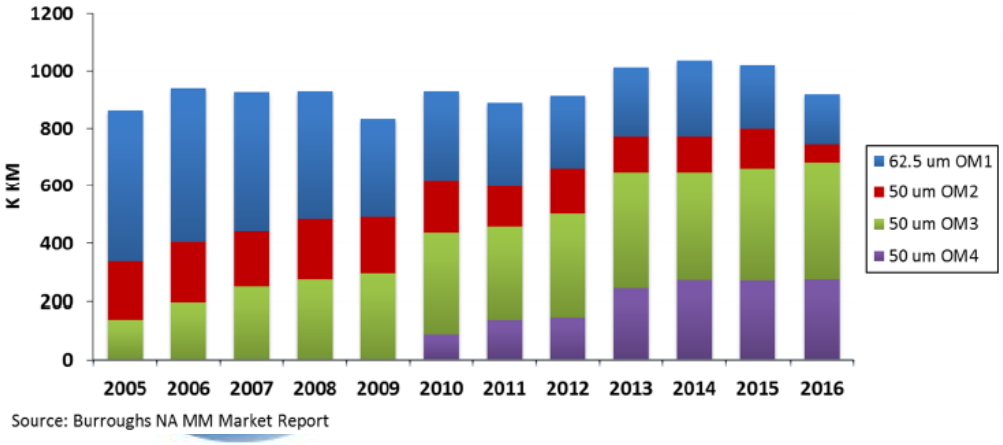


MMFs cannot cope with the capacity needs

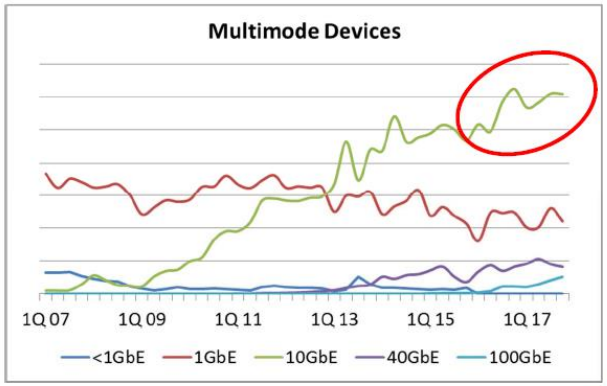
1 Mkm MMF deployed in LANs and DC every year

35% limited to **1 Gb/s or 100 Mb/s** max

80% equipment shipped requires **10+ Gb/s**



Source: Burroughs NA MM Market Report



MMF everywhere but bandwidth limited

Limited bandwidth = Maximum reach decreases when bit rate increase

Maximum reach with MM transceivers (850 nm)	100 Mb/s	1 Gb/s	10 Gb/s
OM1 (62.5/125 µm)	2000 m	300 m	35 m
OM2 (50/125 µm)	2000 m	550 m	80 m
OM3 (50/125 µm)	2000 m	600 m	300 m
OM4 (50/125 µm	2000 m	600 m	500 m

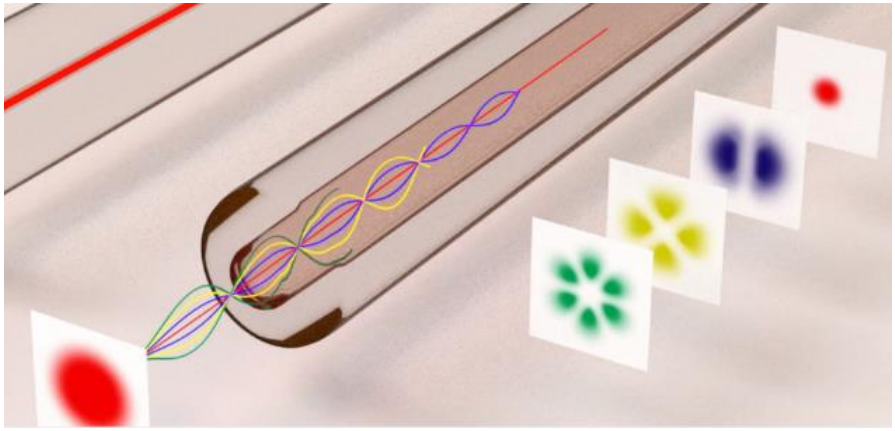
The cause of this limitation: **modal dispersion**

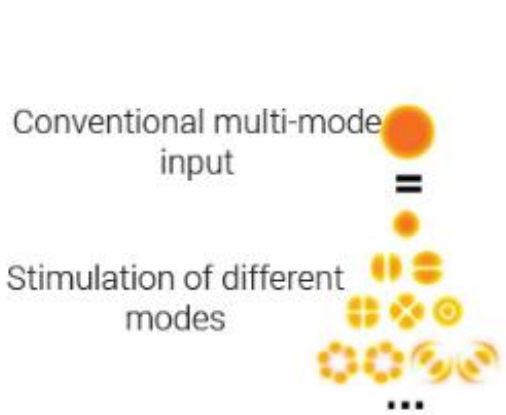
Modal dispersion

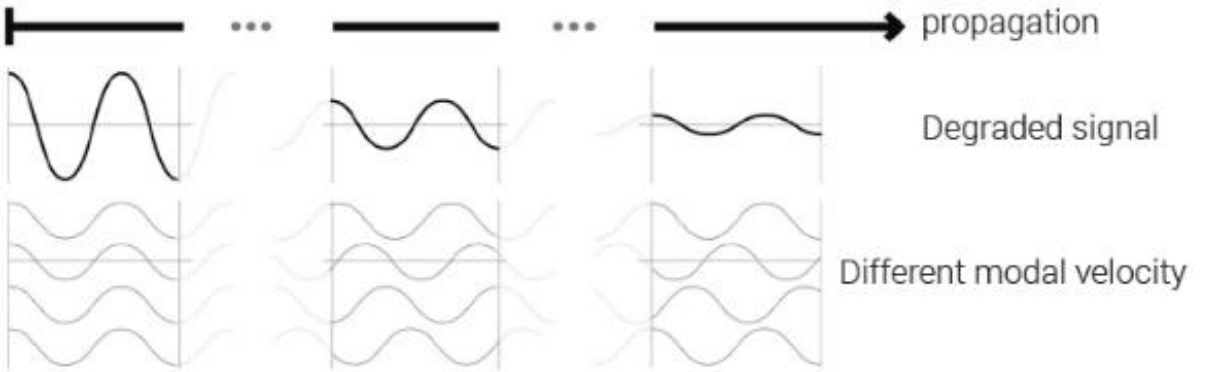
Distorsion mechanism occuring in multimode fibers

Different modal speeds

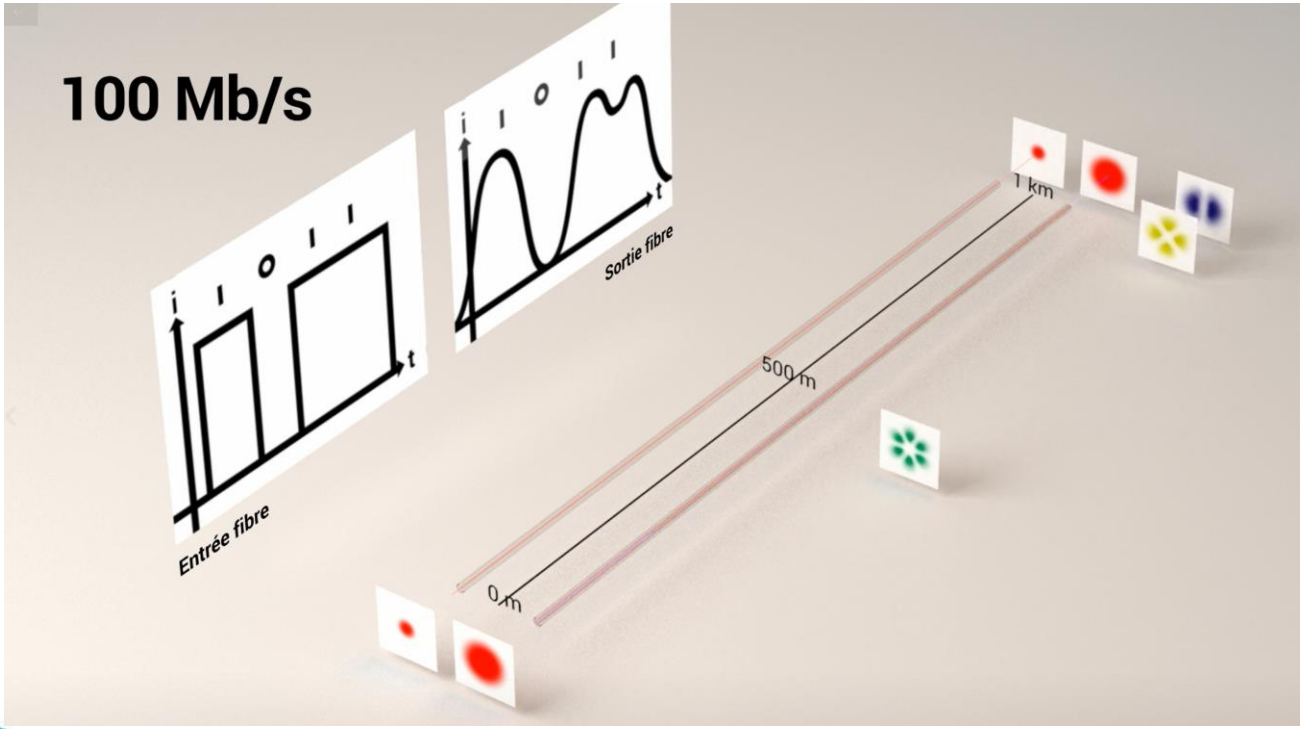
Distorsion of optical pulse during propagation





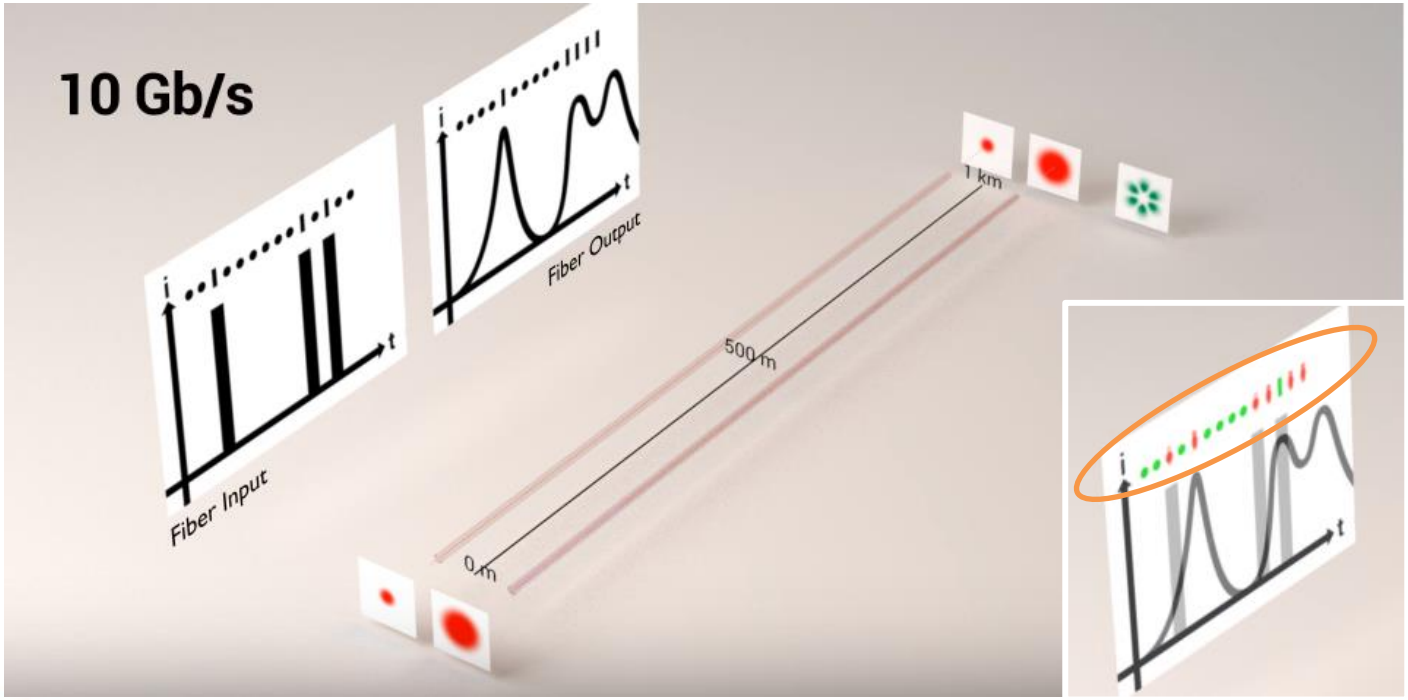


Modal dispersion at 100 Mb/s : minimal impact



Pulse spreading without impact on transmission quality

Modal dispersion at 10 Gb/s : Poor transmission quality



→ Degraded bit error rate

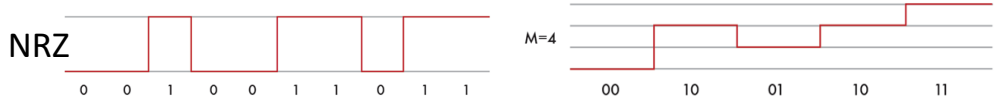
How to increase bit rates over MMF ?

Overcoming the MMF limitation issue?

Advanced modulation format to increase spectral efficiency

Power

- **PAMx** (Pulse-Amplitude Modulation)

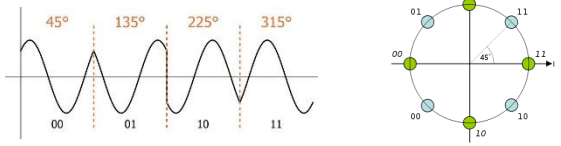


PAM4

PAM4 for 400 GbE

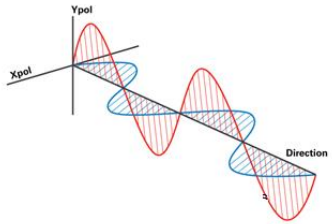
Phase

- **xPSK** (Phase Shift Keying)



Polarization

- **PDM** (Polarisation Division Multiplexing)



Coherent transmissions used for long distances

Expensive hardware needed for all three solutions

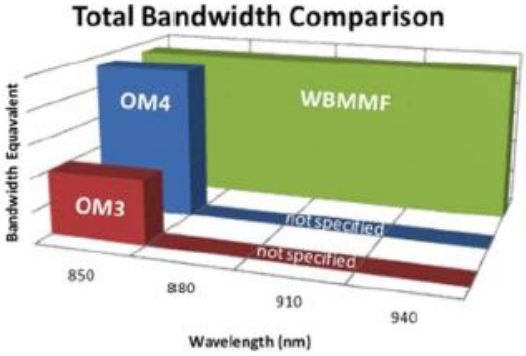
➔ Not compatible with LAN economic models

Overcoming the MMF limitation issue?

Wavelength

Wavelength Division Multiplexing (WDM)

- Enables one to create several channels over one fiber (Channel capacity is still limited by the MMF max capacity)
- Additionnal costs for Mux/Demux and transceivers
  - Ralely used for MMF LAN upgrade
- Sometimes integrated into transceivers: 10GBASE-LX4 (4x2,5Gb/s) ou 100GBASE-LR4 (4x25Gb/s)
- **SWDM over OM5** (Wide Band MMF)
  - New datacenter oriented rather than LAN backbone



Overcoming the MMF limitation issue?

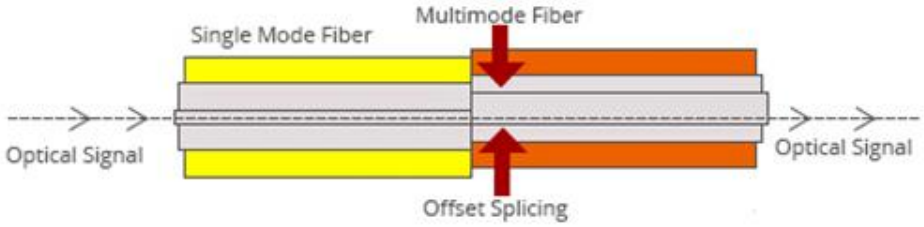
LRM

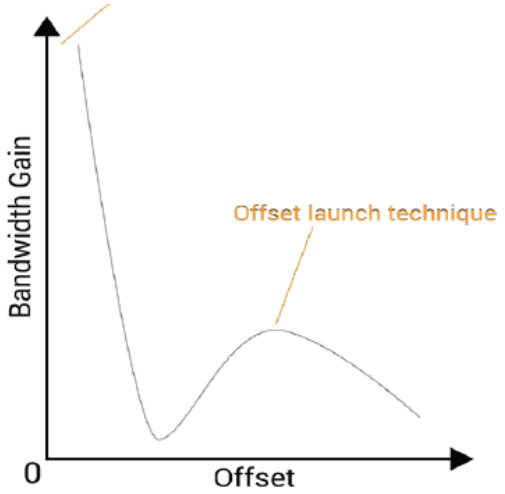
LRM Transceivers (IEEE 802.3aq) + mode conditioning patchcord

- **offset launch** technique : Less excited modes reducing the impact of modal dispersion

+ signal processing : **electronic dispersion compensation** (EDC)

- At 10 Gb/s will not work for OM1 / OM2 fibers longer than 220 m
- Not garanteed to work on all infrastructures





Theoritical MMF bandwidth gain according to launching conditions

Overcoming the MMF limitation issue?

Currently the most common solution is to replace the existing MMF by SMF.

Pros :

- Possibility to **install latest generation fibers**
- Increase of bandwidth over long distances

Cons :

- **Audit** required (availability and condition of the cable ducts)
- **Long and complex** installation
- **Civil engineering work**
- **Expensive** (several tens €/m if complexity)
- Etc.

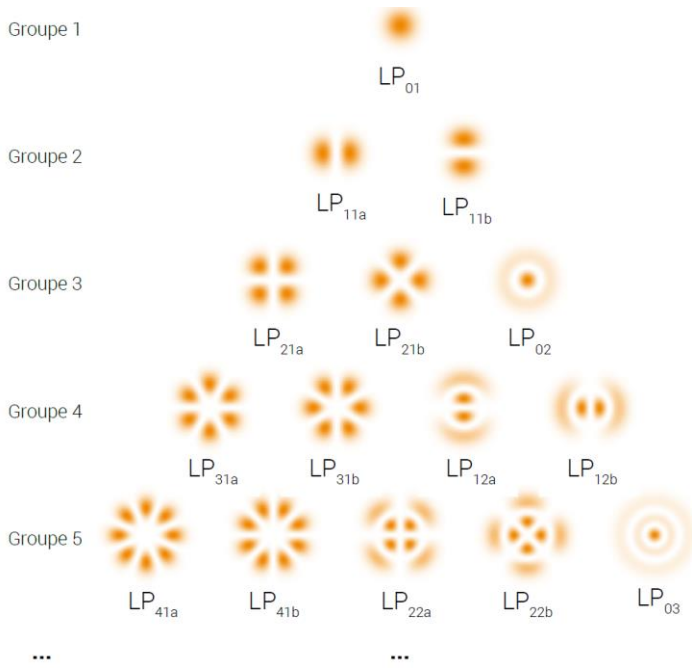
➢ Is there **another alternative** to address the problem of bandwidth limitation in MMF LANs??

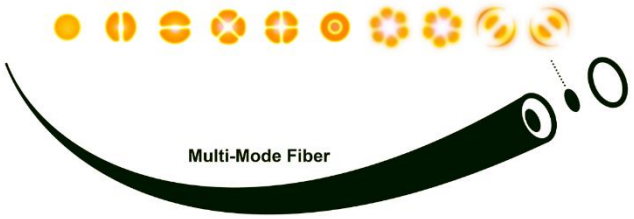
Another dimension: the shape of the light

It is possible to avoid modal dispersion by **coupling and detecting precisely the modes within the MMF**.

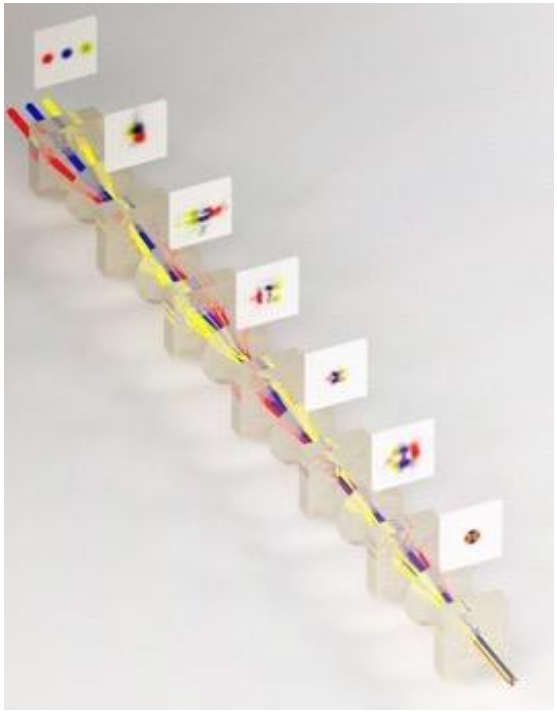
Several solutions to increase bit rates :

- **Excite only one mode** to have a **singlemode transmission**
- **Excite multiple modes** and perform **modal multiplexing**



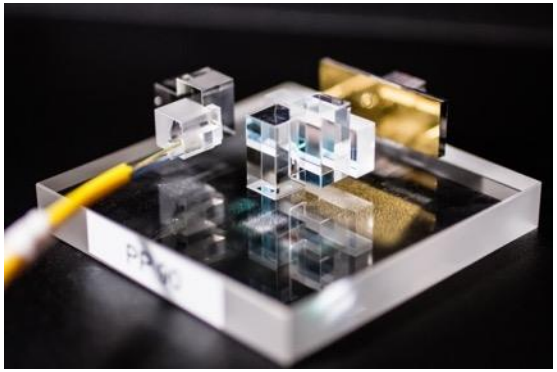


Innovative technology



MPLC : Multi-Plane Light Conversion

Patent Light shaping technology



Derived from **quantum optics**

Passive optical process with low loss

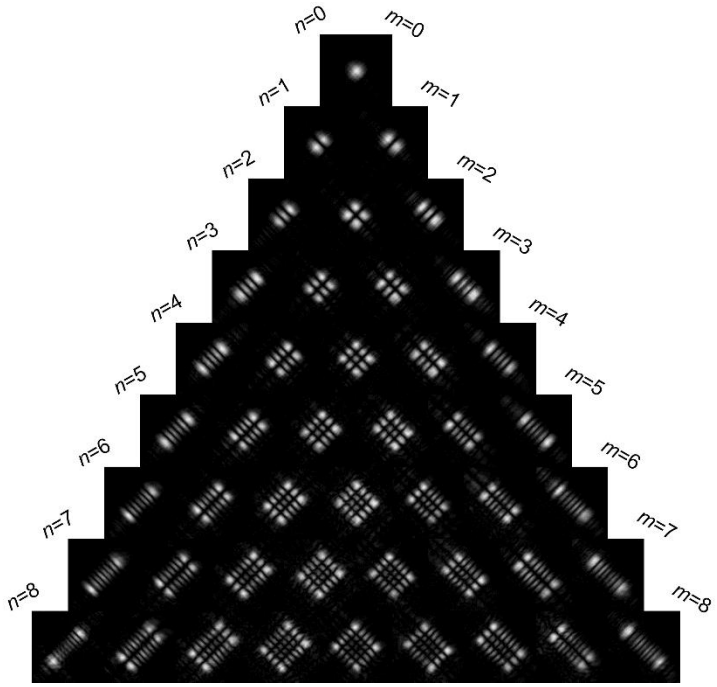
Multiple light shape through **reflections on textured surfaces**

Addressing of all the MMF modes

Today, MPCL is able to address **45 modes of an multimode fiber**

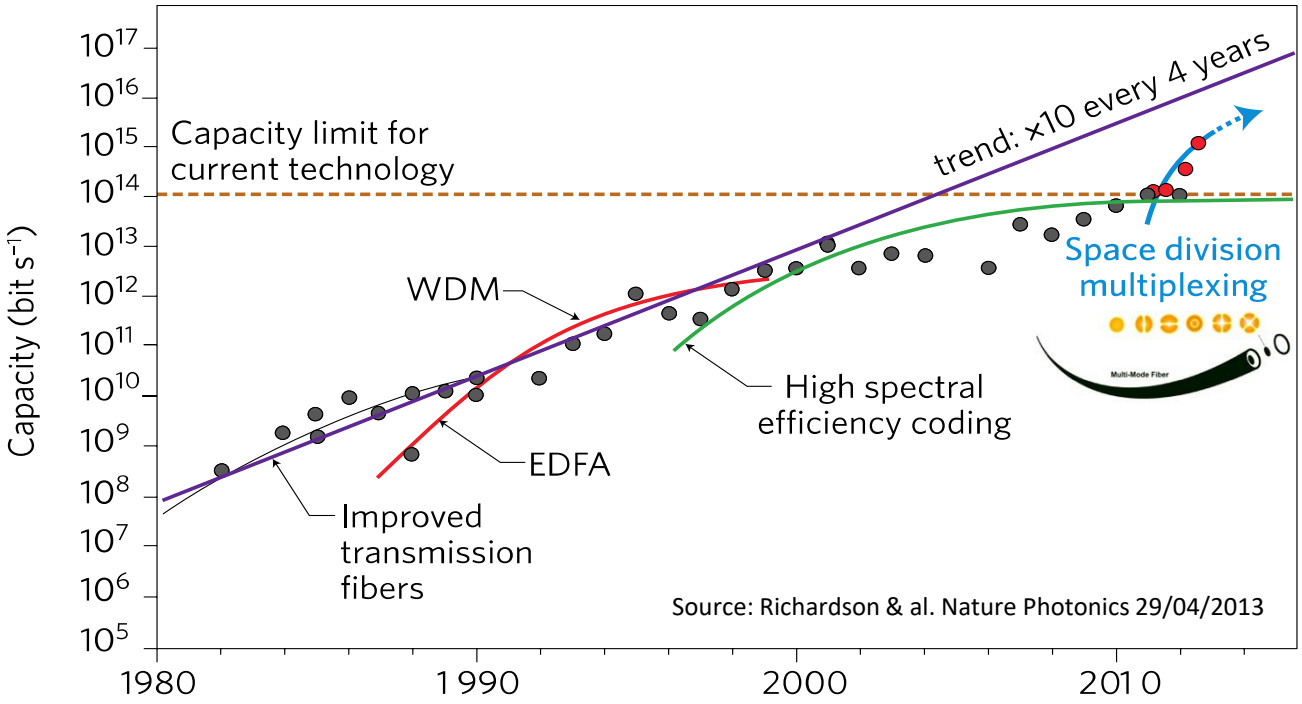
New opportunity for optical communications

- **Space Division Multiplexing (SDM)**



S.Bade et al., PDP, OFC 2018

Limit at 100 Tb/s per fiber with current technologies



SDM opens new perspectives

New horizons

A **world record** by KDDI (Designing The Future) : MPLC technology has allowed to transmit 10 Peta-bit/s (10 million Gb/s!) over a single fiber

- Equivalent to **30 times of the current worldwide internet bit rate**
- Equivalent to **500 million of europeans simultaneously watching Netflix in 4k**

Lab experience over non-standard MMF, combining SDM through MPLC, WDM and advanced modulation format

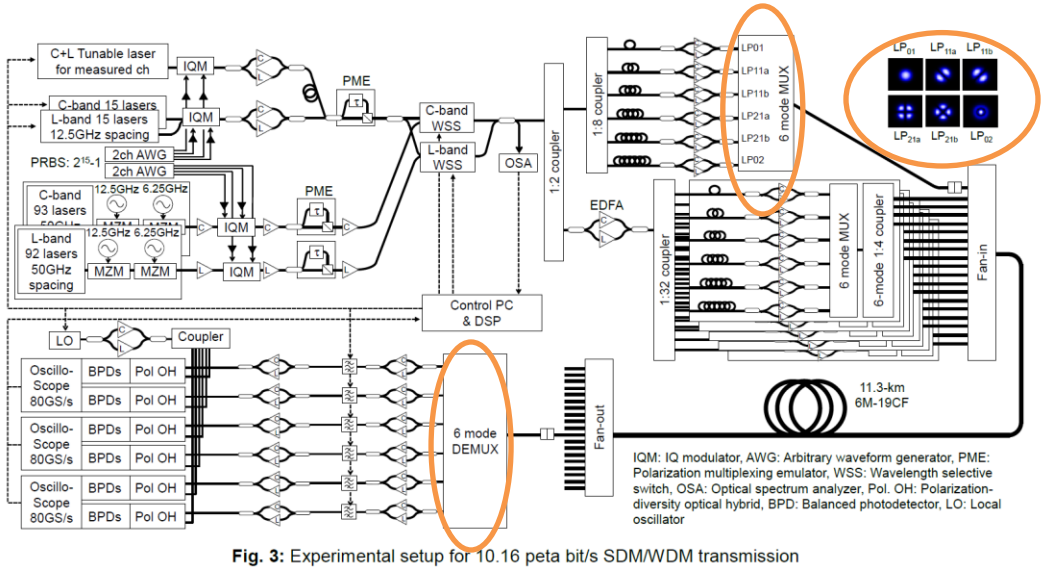


Fig. 3: Experimental setup for 10.16 peta bit/s SDM/WDM transmission

D.Soma et al., KDDI Research, PDP, ECOC 2017

High bit rates over legacy MMF

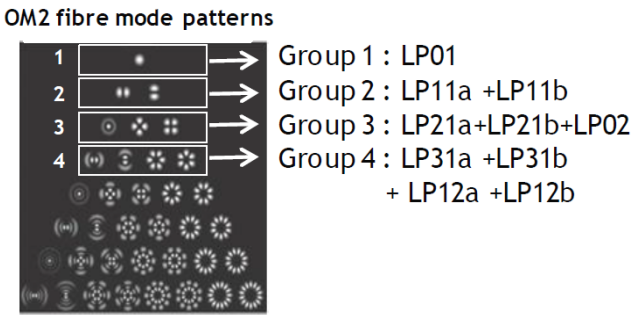
200 Gb/s over 4.4km of OM2

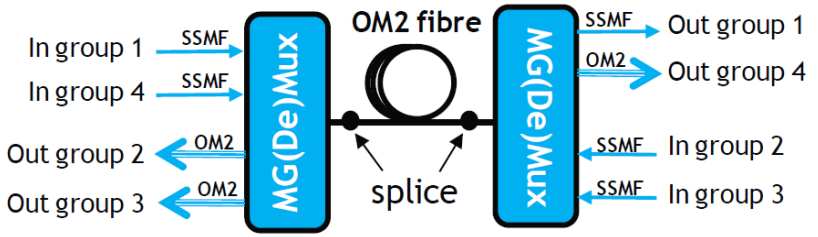
NOKIA Bell Labs

Modal multiplexing using MPLC (4 mode groups)

50Gb/s PAM4 over each modal channel

Direct detection





C. Simmoneau et al., OFC 2016

Bicsi

High bit rates over legacy MMF

14,5 Tb/s over 2.2km of OM2 NOKIA Bell Labs

Combining MPLC + WDM

4 mode groups x 20λ per group ie 80 channels (each channel at 180 Gb/s DMT)

- **Highest data rate ever transmitted over an optical multimode fiber with intensity modulation and direct detection**

K. Benyahya et al., ECOC 2017, OFC 2017

Solutions to upgrade LAN cabling infrastructure

MPLC technology used in **products range** to exploit the full potential of multimode fiber **by removing bandwidth limitation**

Increased capacity

High capacity channels (10+ Gb/s), for **MMF up to 10km**

Several ranges **depending on the network topology** (point to point, star, POL)

WDM compatible

Compatible with standard fibers and transceivers

Any type of **multi-mode fiber 62.5/125 µm or 50/125 µm**

Any type of **single-mode transceiver**

Transparent to communication protocol (ethernet, fiber-channel…)

Reduced cost

3 times less expensive than a fiber roll-out; **up to 10 times** less expensive if complexities exist

Passive system: no additional cost of consumption, cooling, monitoring

Installation takes **only few hours**

Unique technology for a global problem

The problem of MMF bandwidth limitation is found on various typologies and topologies of networks

- University / School group
- Hospital
- Factory
- Military sites
- Shopping center
- Ski resort
- Urban community
- Amusement park
- Airport
- Sports complex
- Museum
- …

Let’s analyze some use cases

Smart factory

Auto factory in Canada, **OM1 MMF** (570 to 710m), **limited at 100 Mb/s**

Capacity needed 10 Gb/s over several links

- New CCTV system
- « smart factory » - various equipment controlled by WiFi

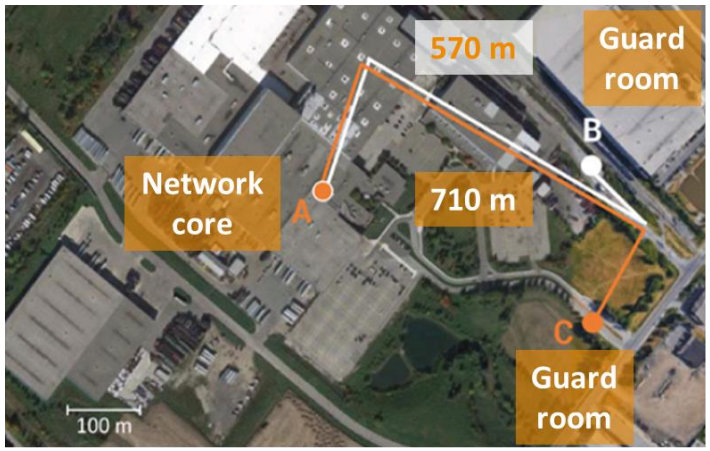
No free cable conduits under buildings and parkings

➢ **Can not block site entries for civil engineering** (24/24-7/7 site)

✓ MPLC technology at the network core

10 Gb/s over each link, with an easy upgrade path to 40-100 Gb/s

4 hours of installation vs days for fiber roll out



Transforming up to 6 MMF pairs into 6 SMF pairs

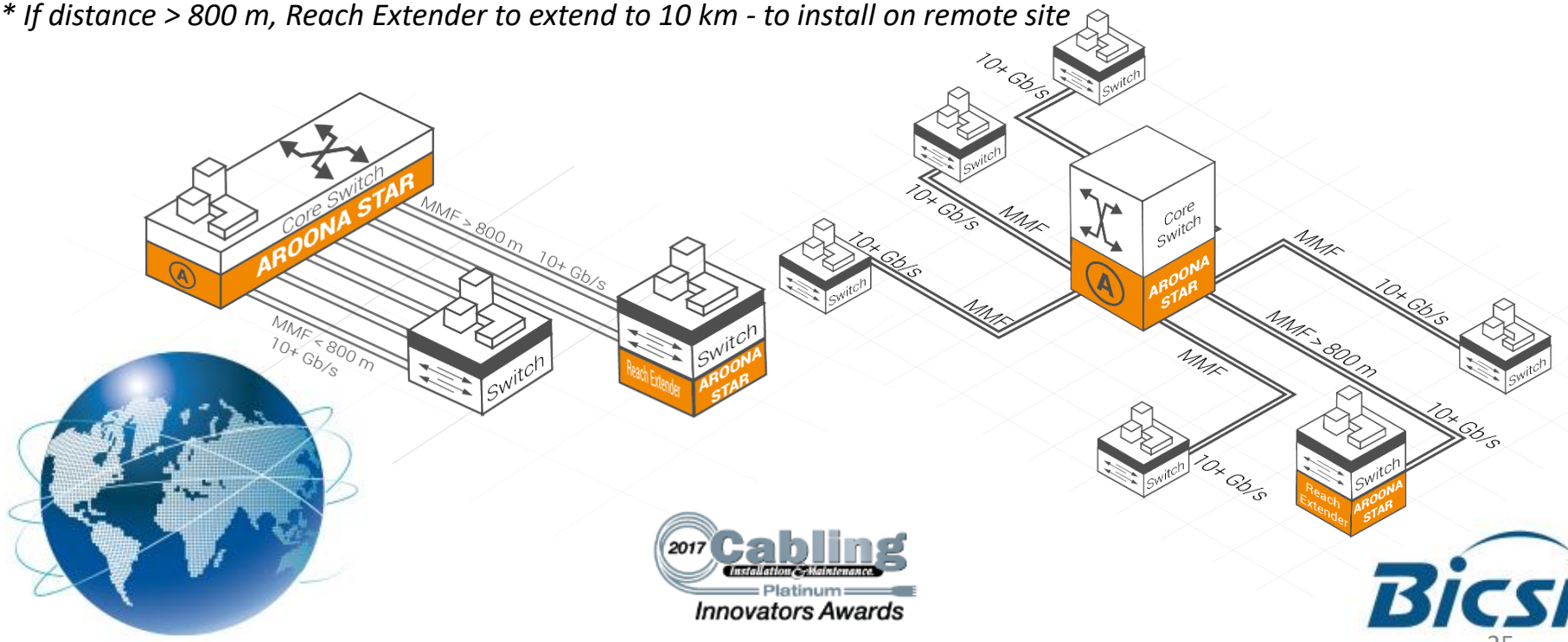
Upgrades the network with a **single component**

- 10 Gb/s over all branches of a LAN (instead of 1Gb/s or 100Mb/s)
- **Up to 6 duplex links** of 800 m*
- WDM compatible

AROONA-STAR **only at the core of the network**

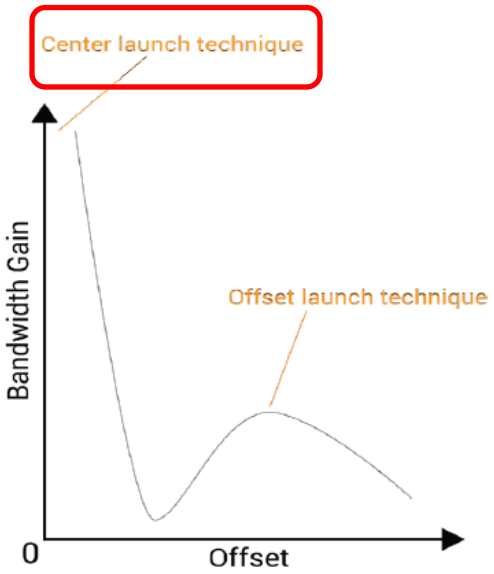
No installation required at remote sites*

** If distance > 800 m, Reach Extender to extend to 10 km - to install on remote site*

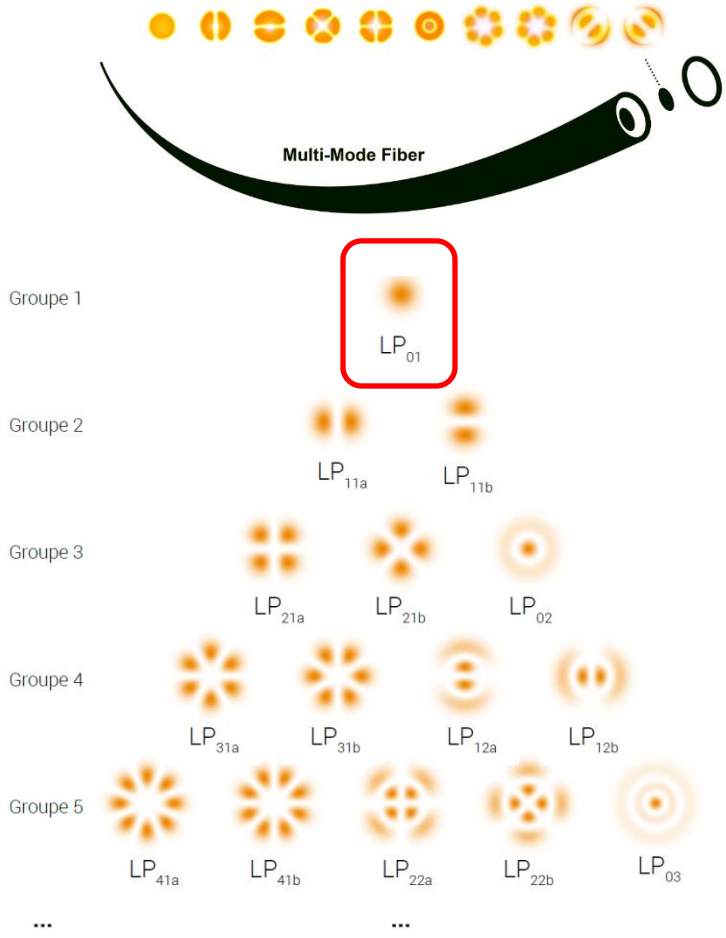


2017 Cabling Installation & Maintenance Platinum Innovators Awards

Transforming MMF into SMF

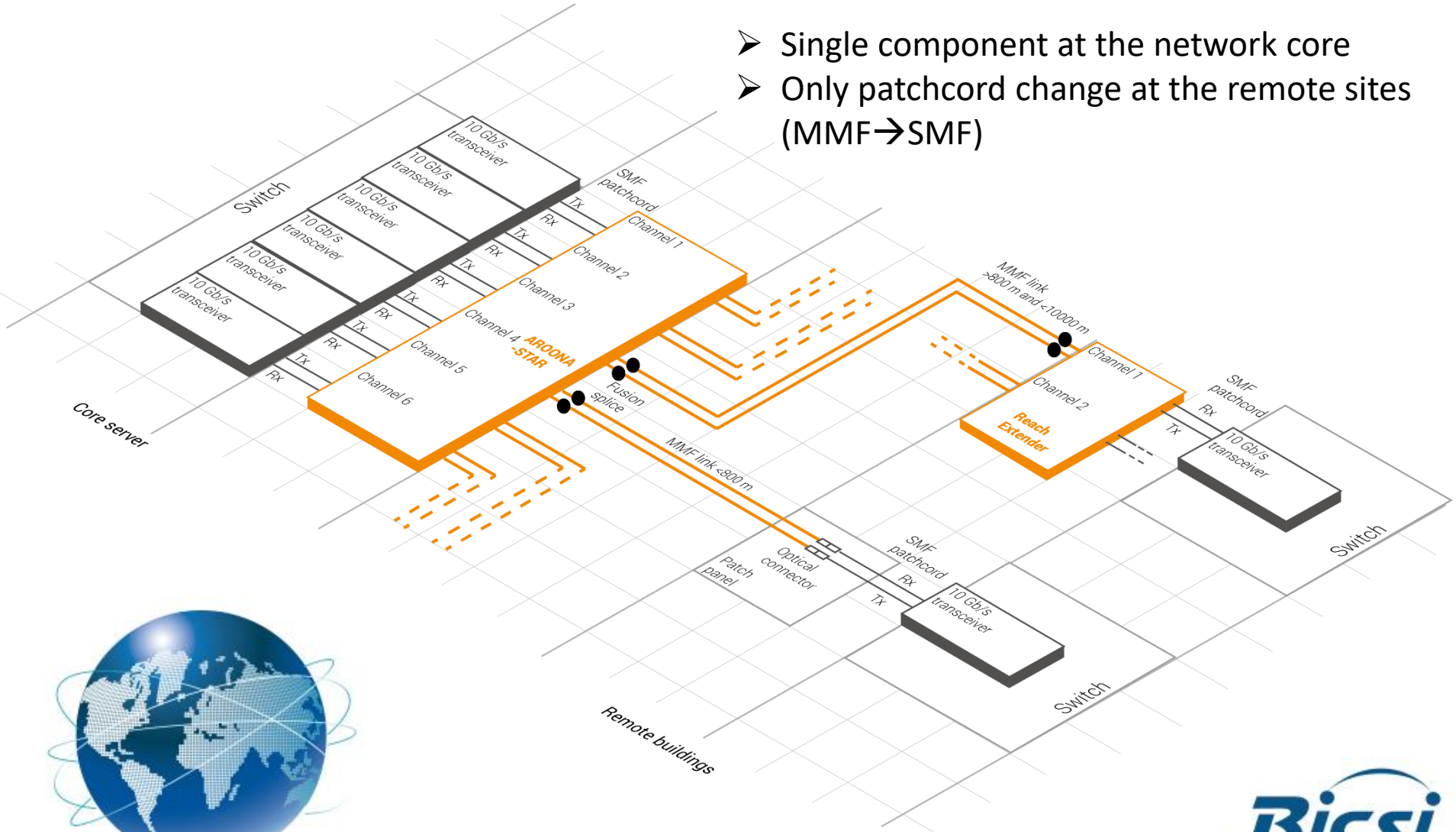


Theoritical MMF bandwidth gain according to launching conditions



Transforming up to 6 MMF pairs into 6 SMF pairs

- Single component at the network core
- Only patchcord change at the remote sites (MMF→SMF)



Better connectivity at school

School district in Arkansas, US

Severals OM1 links **between 130 et 530 m**, limited at 1 Gb/s, star topology

Innovative program « **one student, one computer** »

10Gb/s needed for DAS (Distributed Antenna System)

- Infrastructure upgraded in 1 day – financial savings
- 5 additionnal equipements ordered to upgrade the entire network

Futur proofing a factory network

Cabling infrastructure in OM1 only – 12km² campus

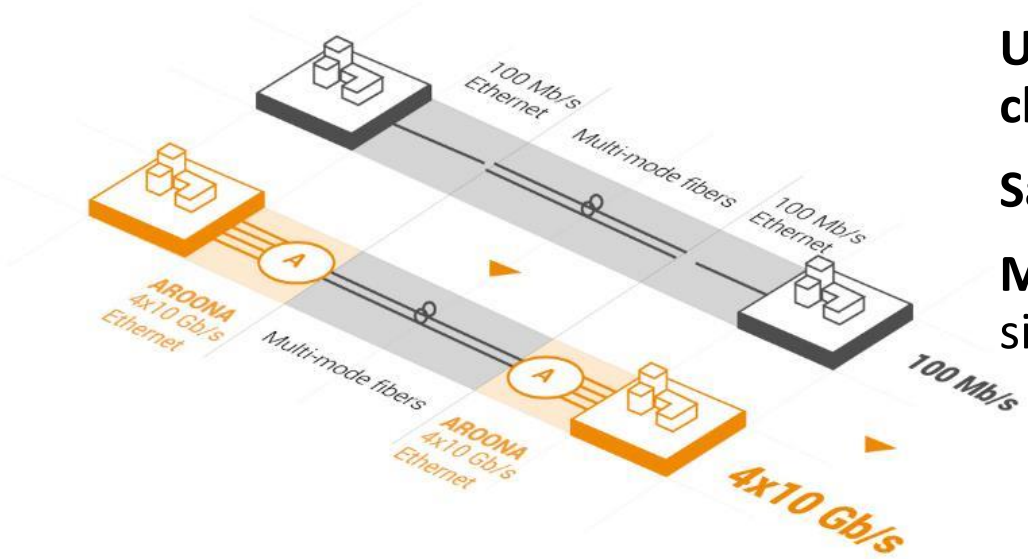
10 Gb/s needed (CCTV, specific applications,…)

Only few MMF available : wish to multiply links

No free cable conduits – risky civil engineering on a steel industry **SEVESO site**

- MPLC solution to obtain **4 channels at 10 Gb/s over a 2800m OM1 single pair**
- Upgrade **done in ½ day**
- **Other project soon to create an MMF 10 Gb/s optical ring over the entire campus**

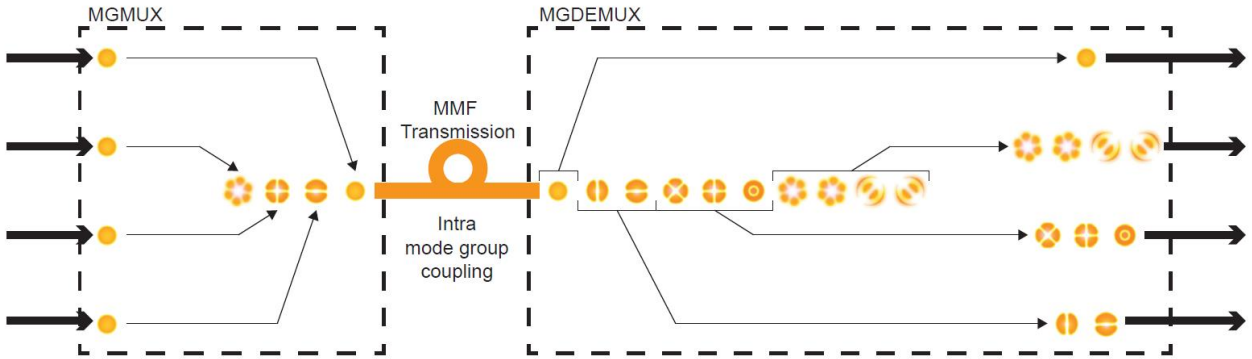
Transforming 1 MMF pair into 4 SMF pairs



Up to 4 high bit rates independent channels over 1 MMF pair

Same wavelength

Modes are muxed / demuxed on each side of the link using MPLC technology



Connected ski resort

OM1 MMF (**3.3km – 3200m high**), limited at 50 Mb/s

MMF initialy dedicated to ski lift sensor monitoring

High capacity needed for smart ski resort

No cable conduits available – **Highly complex** fiber roll out in montain context

MPLC solution to deal with this issue:

2x10 Gb/s over OM1 MMF

1 day of installation vs weeks for civil engineering for cable deployment

Passive Optical LAN over MMF

POL is the future of LAN implementation…

Passive Optical LAN is an attractive, long-term LAN architecture that **outperforms traditional Ethernet LAN in capacity**, installation and operational cost, energy savings, infrastructure footprint and security.

It benefits from the Gigabit Passive Optical Network (GPON) technology for access networks and brings fiber-speed connections to the desktop.

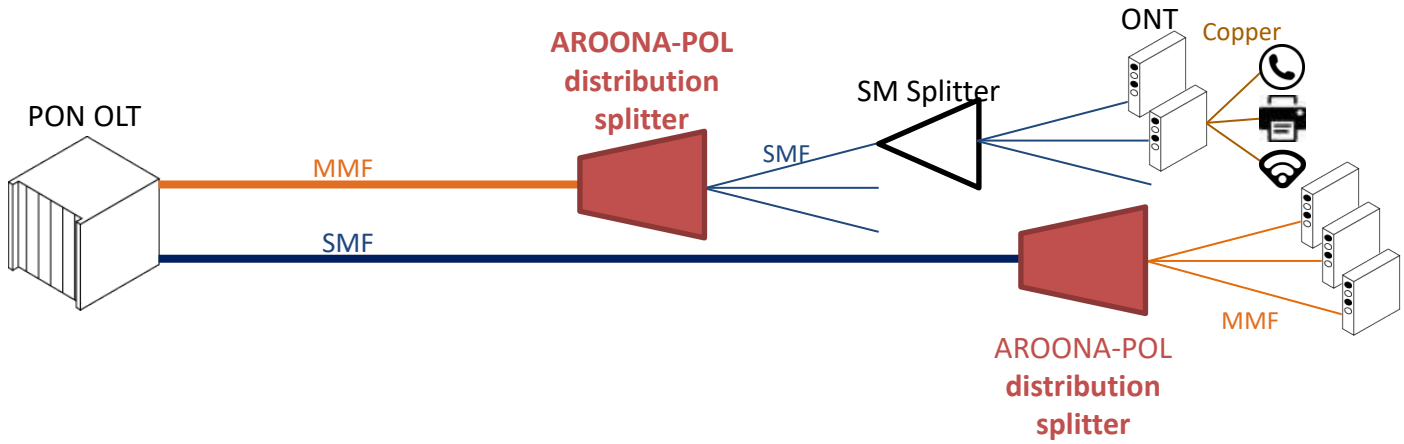
… but backbone/vertical singlemode fiber recabling may be deterrent to POL adoption

association for passiveopticalLAN

Presentation on this topic:
15:20 - 16:00 ***Slobodan Zlatković – APOLAN Consortium***

Retrofitting old infrastructure for POL

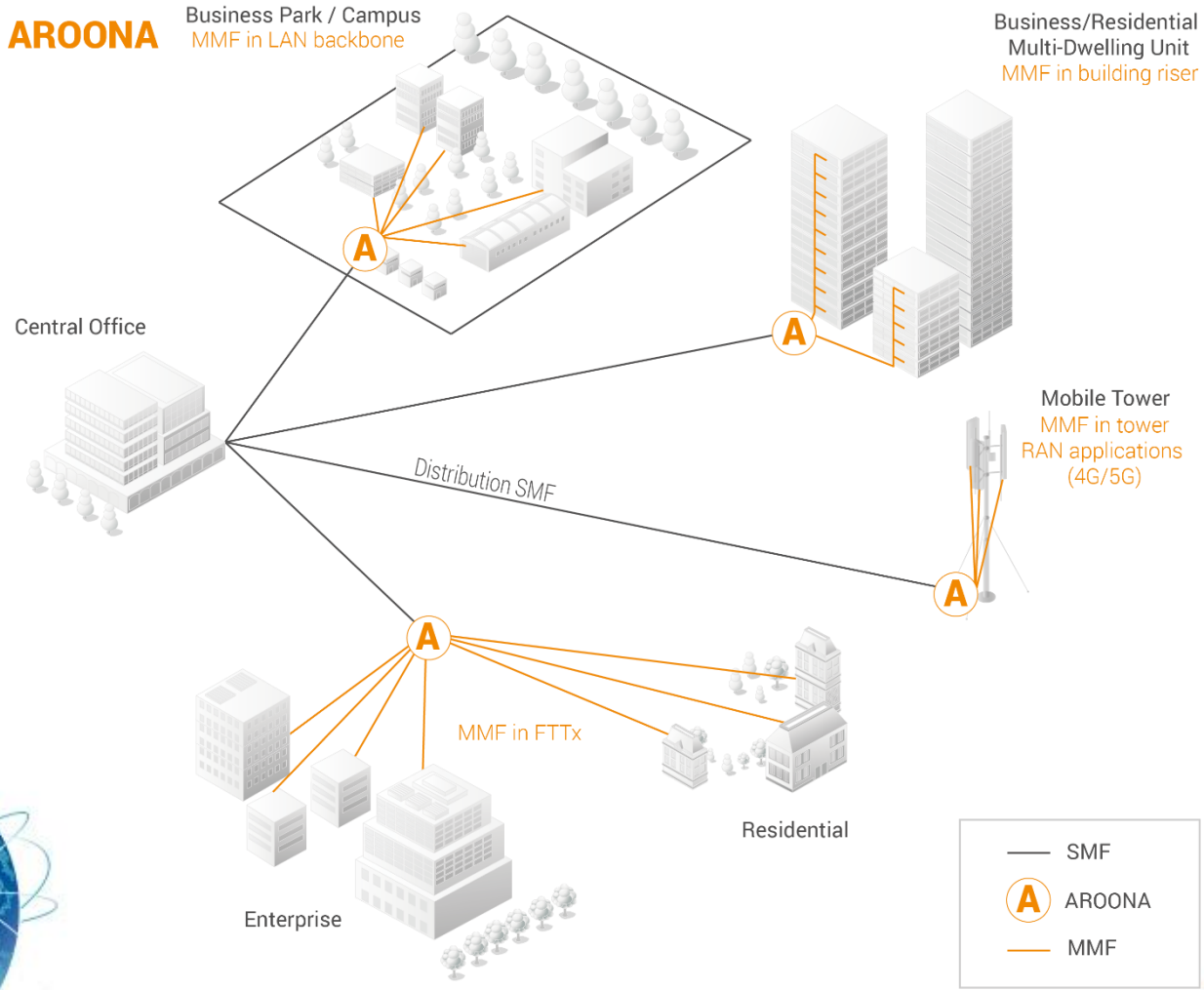
MPLC technology **facilitates POL adoption over MMF cabling infrastructure**



Simultaneously manages the spatial modes in upstream and downstream operation between singlemode fibers and multimode fibers.

2016 APOLAN Member Award
~ INNOVATION ~
Leadership in building marketing awareness for fiber-based enterprise networks

SM to MM modal adaptation use cases



Transforming MMF into SMF, it is possible !

Local Area Network fiber plant mainly with multimode fiber

MMF = bandwidth limitation

MPLC (Multi-Plane Light Conversion)

Light shaping innovative technology **to harness the full potential of MMF**

Overcome modal dispersion to increase MMF capacity

A full range of passive equipment as **an alternative to fiber cabling** to meet ever growing bandwidth demand

Everywhere you find multimode fiber, MPLC technology by Cailabs brings you solutions

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Any question ?

Grazie per l'attenzione. Non esitate a contattarmi se volete maggiori informazioni o demo

- kevin@cailabs.com

More information on www.cailabs.com

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