10 Gigabit Ethernet over Multimode Fiber

Which option is best for your network?

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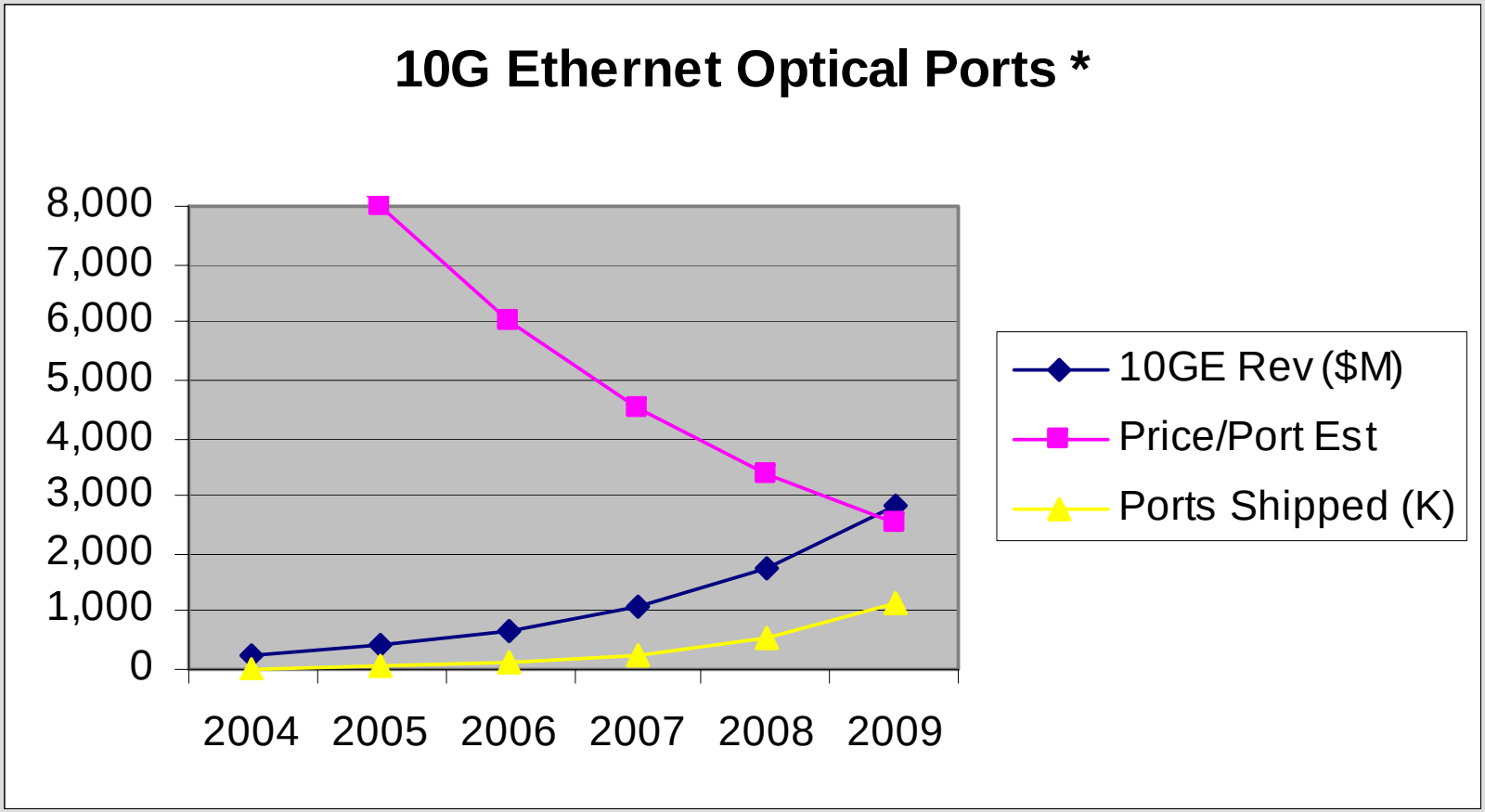
10 Gigabit Ethernet over Multimode Fiber

Outline

- **Market View**
- **Standards and Technology Options**
- **System Cost Comparison**
- **Application Guidelines**

10 Gb/s Ethernet Ramping

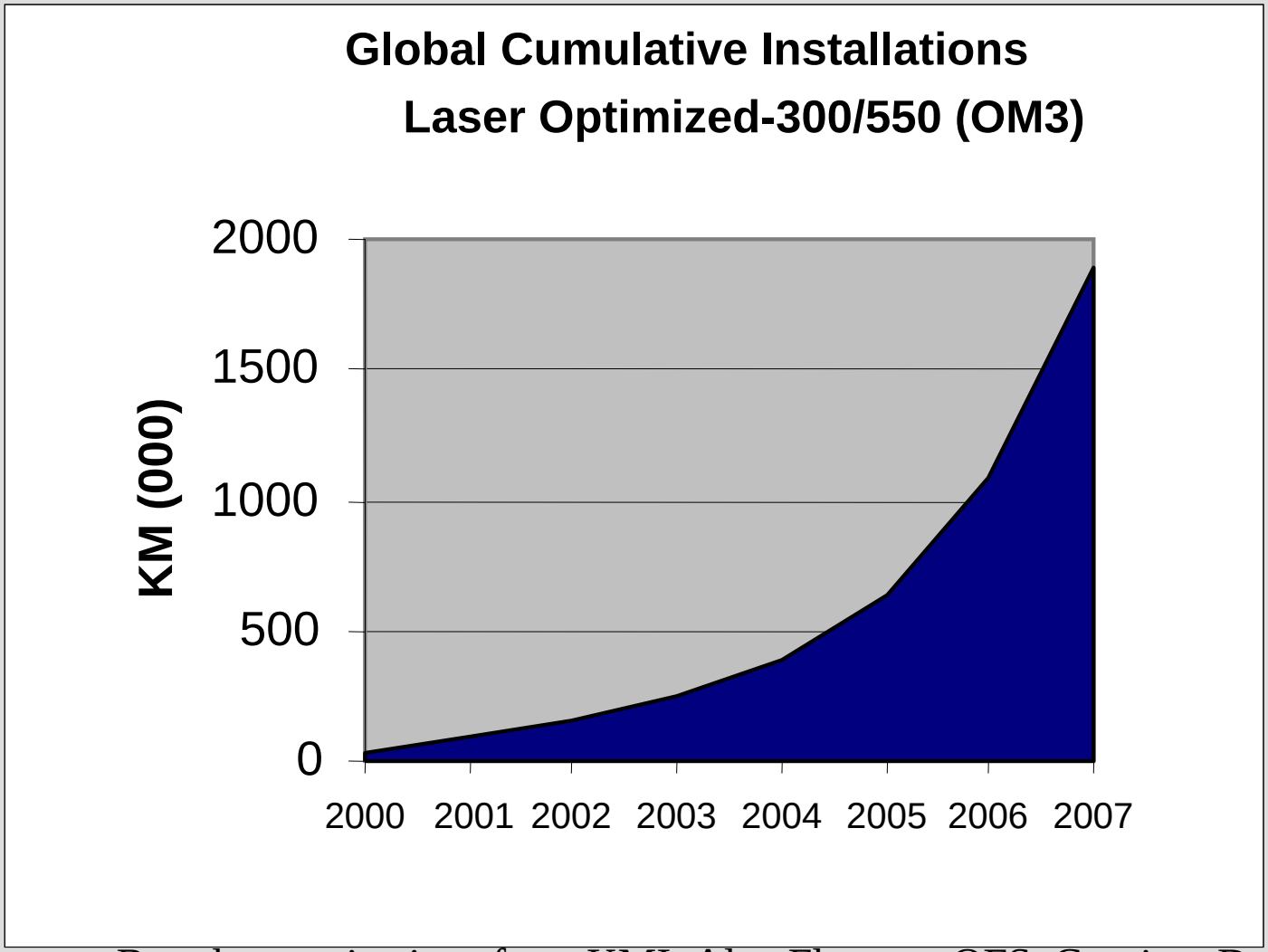
Driven by bandwidth demand and lower cost of ports



Fiber Dominates 10GE: 82% of ports projected to be optical. Could be 95 - 100% depending 10GBASE-T viability

* Source: OFS (JEG) Estimate Based on CIR 12/04 PR for report titled 10-GIGABIT NETWORKING: A MARKET AND TECHNOLOGY ASSESSMENT

Laser Optimized 50 micron fiber (OM3) base growing quickly
Supports lowest cost 10GBASE-SR Ports to 300m



Source: Based on projections from KMI, Alan Flatman, OFS, Corning, Draka

Can installed base of MMF support 10G to 300 meters?

It depends on the fiber, and don't forget cost!

	10GBASE-SR (30 – 50% lower system cost)	10GBASE-LX4	10GBASE-LRM (IEEE draft std, 2006 publication)
OM3 50 micron 2000/500 MHz-km	**300 meters**	**300 meters***	**300 meter goal***
OM2 50 micron 500/500	**82 meters**	**300 meters**	**300 meter goal**
FDDI / OM1 62.5 micron 160/500 200/500	**26 / 33 meters**	**300 meters**	**300 meter goal**

OM3 fiber vs.. lower grades:

Saves ~$2500/link if used with SR

~$500/link if used with LX4 and LRM

OM3 with SR vs.. singlemode with LR: saves ~$2000/link

Savings based on 2005 list prices

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10 Gigabit Ethernet – 850 nm Serial LAN PMD

Lowest cost support for 10 GE Optical links

10GBASE-SR *(Available from multiple sources)*

Description	62.5 μm MMF		50 μm MMF			Unit
Wavelength	850					nm
Modal bandwidth (min)	160	200	400	500	**2000***	MHz-km
Operating Distance (max)	25	33	66	82	**300**	meters

LO-550 fiber: **4700 MHz-km*** ***550 meters***

LO-300 fiber: **2000 MHz-km*** ***300 meters***

•Effective Modal Bandwidth per 60793-2-10, assured by DMD or EMBc measured in accordance with IEC 60793-1-49

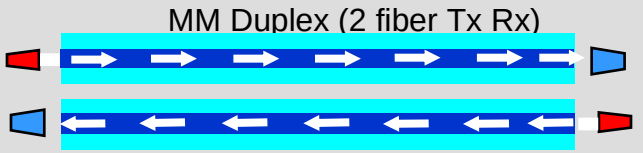
10G BASE-SR over LO-50 micron MMF (OM3)

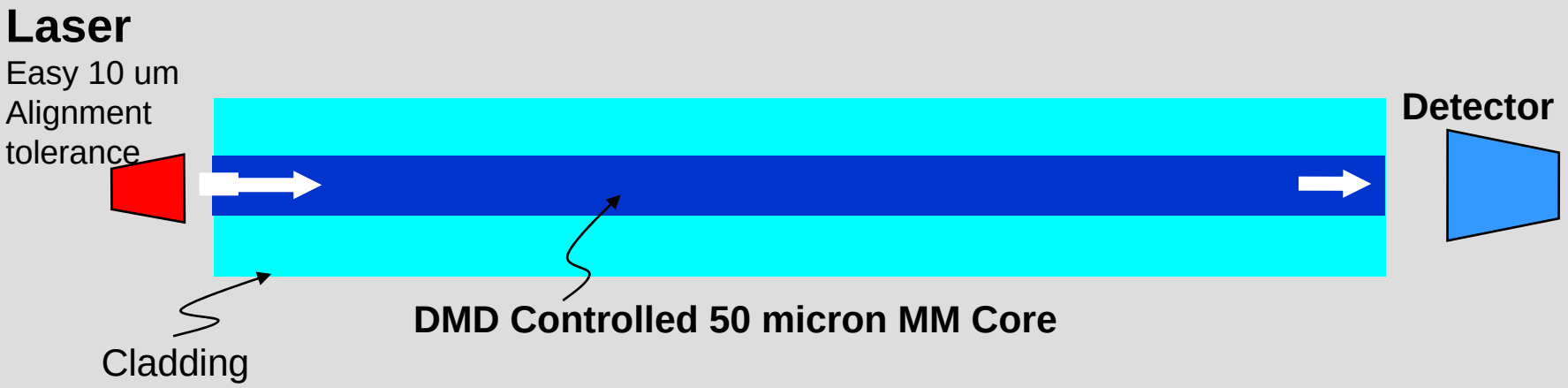
10G Ethernet 850nm new or upgrade:

10GBASE-SR up to 550 meters

1G Ethernet 850 nm legacy support:

1000BASE-SX: up to 1100 meters





Relaxes tolerances for Laser to Core (10 times easier than SM)

- **Enables lowest cost optics, materials, packaging, and connectors**

Leverages existing 1G Ethernet manufacturing capacity (>10M/yr)

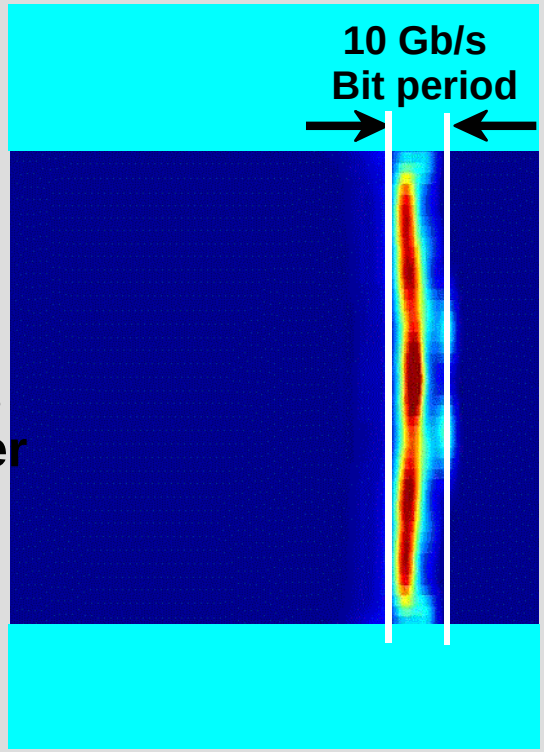
- **80 - 90% of Gigabit Ethernet optical ports are 850 nm**

Same connectors and installation as conventional multimode fiber

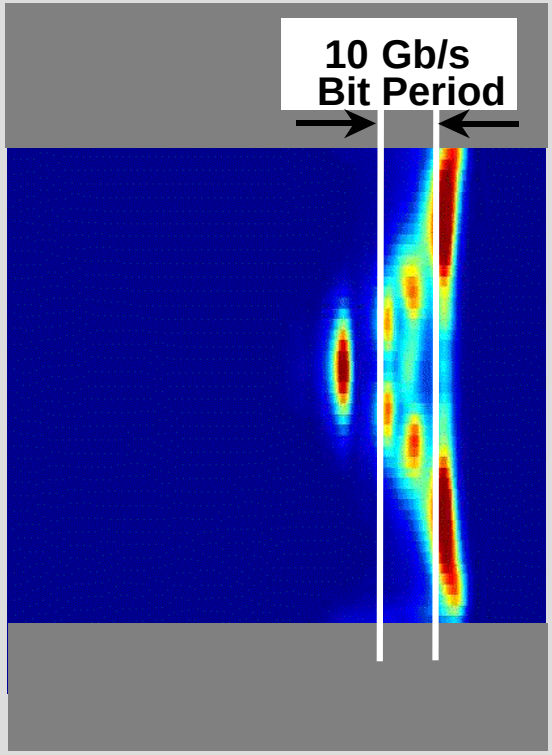
Laser Optimized 50 micron Multimode Fiber

Designed to support low cost Laser-based 850 nm systems

LO 50 micron fiber (OM3)



Conventional
50 or 62.5 micron



Received pulse at 10 Gb/s over 300 meters

Std 62.5 and 50 micron fiber

Cannot support low cost 10GBASE-SR to 300 meters

Bits Collide and Link Fails!

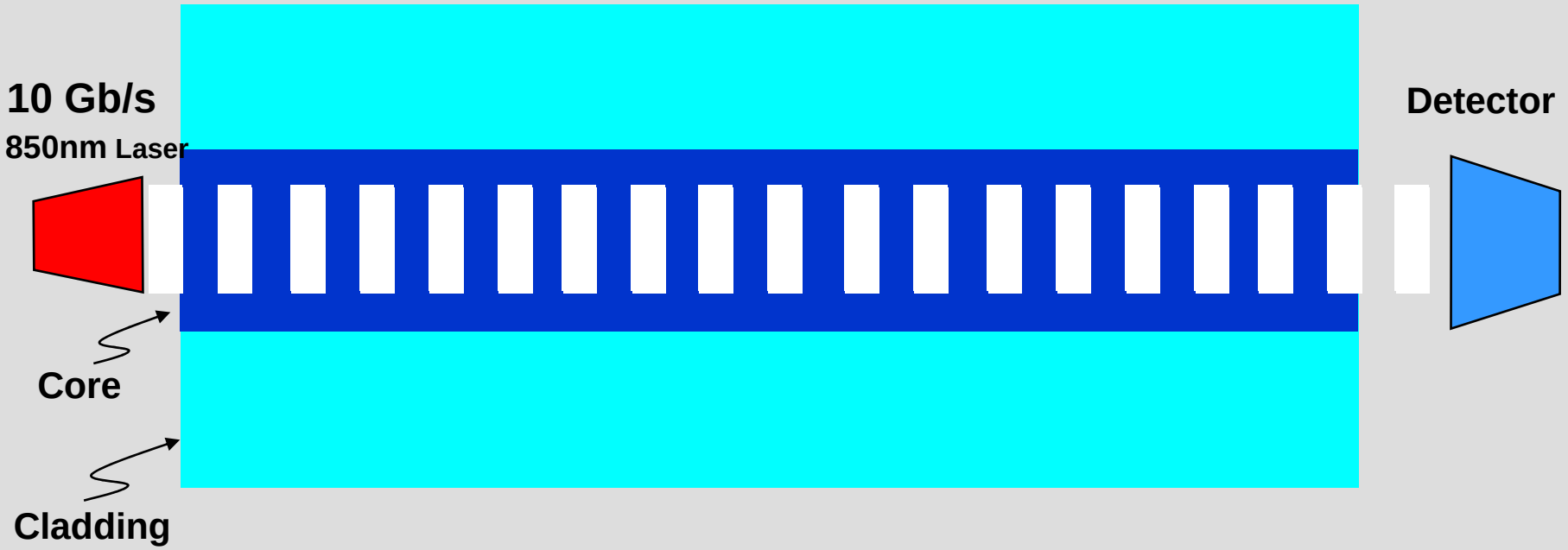
Conventional fiber - 50 or 62.5 micron

Supports only 25 - 82 meters at 10 Gb/s

Laser Optimized 50 Micron fiber (OM3)

Enables low cost 10GBASE-SR for backbones or to desktop

10 Gb/s reliable transmission, design flexibility



How? Laser Optimized 50 MM fibers control DMD to support

10 Gb/s up to 300 or 550 meters

10 Gigabit Ethernet

Std 62.5 and std 50 micron Installed MMF support – at higher cost

From IEEE 802.3

10GBASE-LX4

(Available from multiple sources)

Description	62.5 μm MMF		50 μm MMF			Unit
Wavelength	1275, 1300, 1325, 1350					nm
Fiber Type	FDDI	OM1		OM2	**OM3**	
Modal bandwidth (min)	500	500	400	500	**500**	MHz-km
Operating Distance (max)	300	300	240	300	**300**	meters

Conventional MMFs (FDDI, OM1, 400/400, OM2)

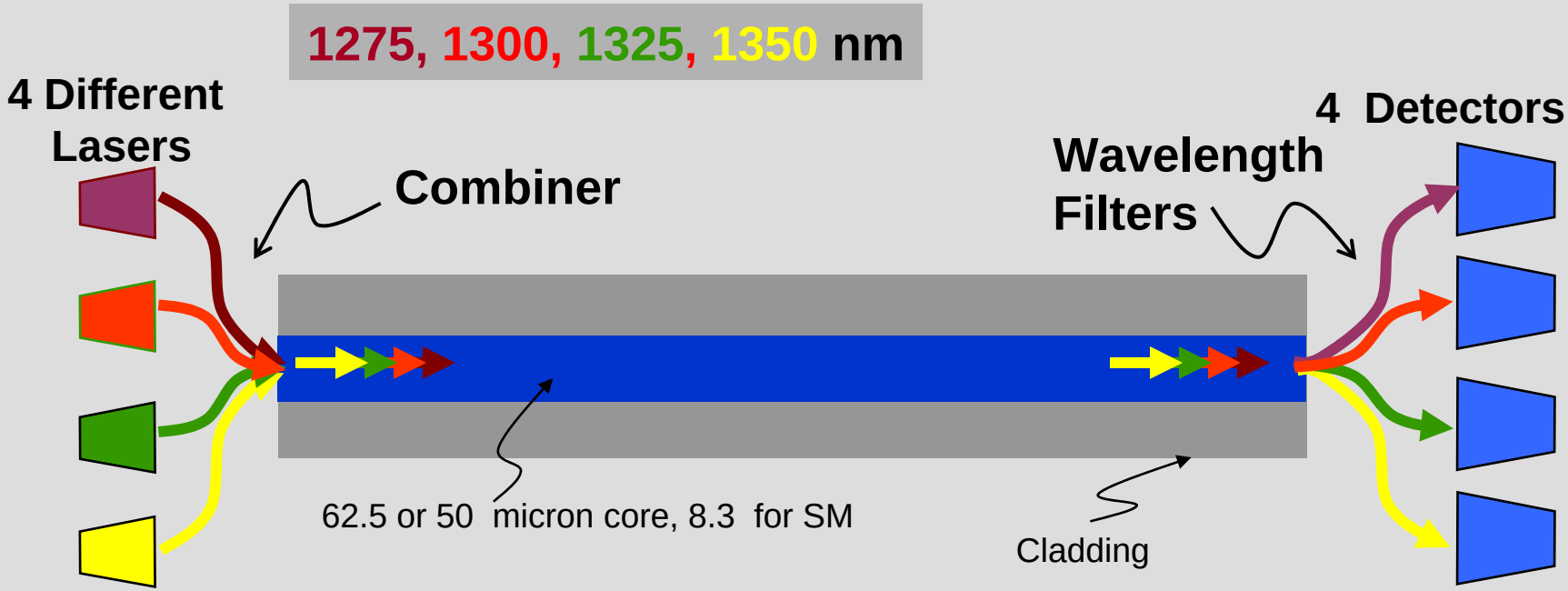
- **Mode conditioning patch cords REQUIRED per 802.3 clause 38**
  - **~$600 per link**

LO-50 micron (OM3) fiber:

- **DOES NOT require mode conditioning patch cord**

10GBASE-LX4 - CWDM to support conventional MMF

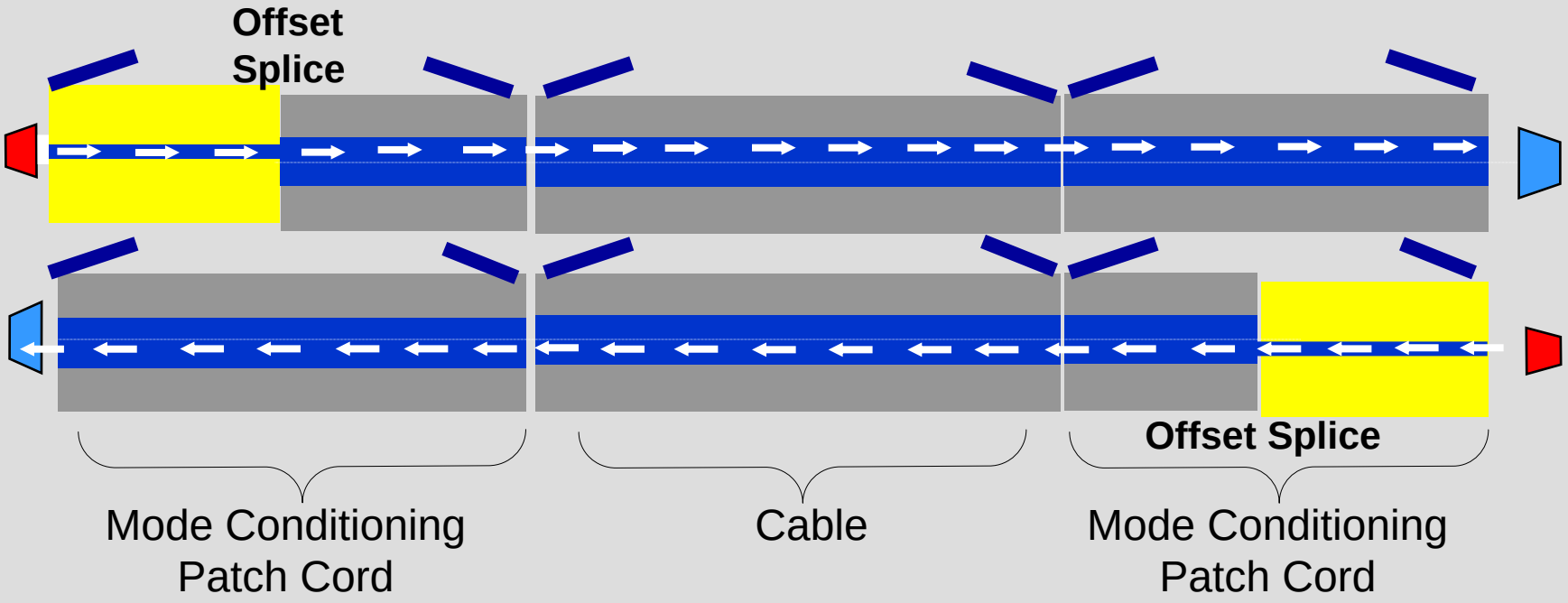
Divides 10G into four 2.5G streams to support 300m



- **High cost SM packaging, plus more parts and complexity**
- **Requires “mode conditioning patch cord” if used with conventional MMF**

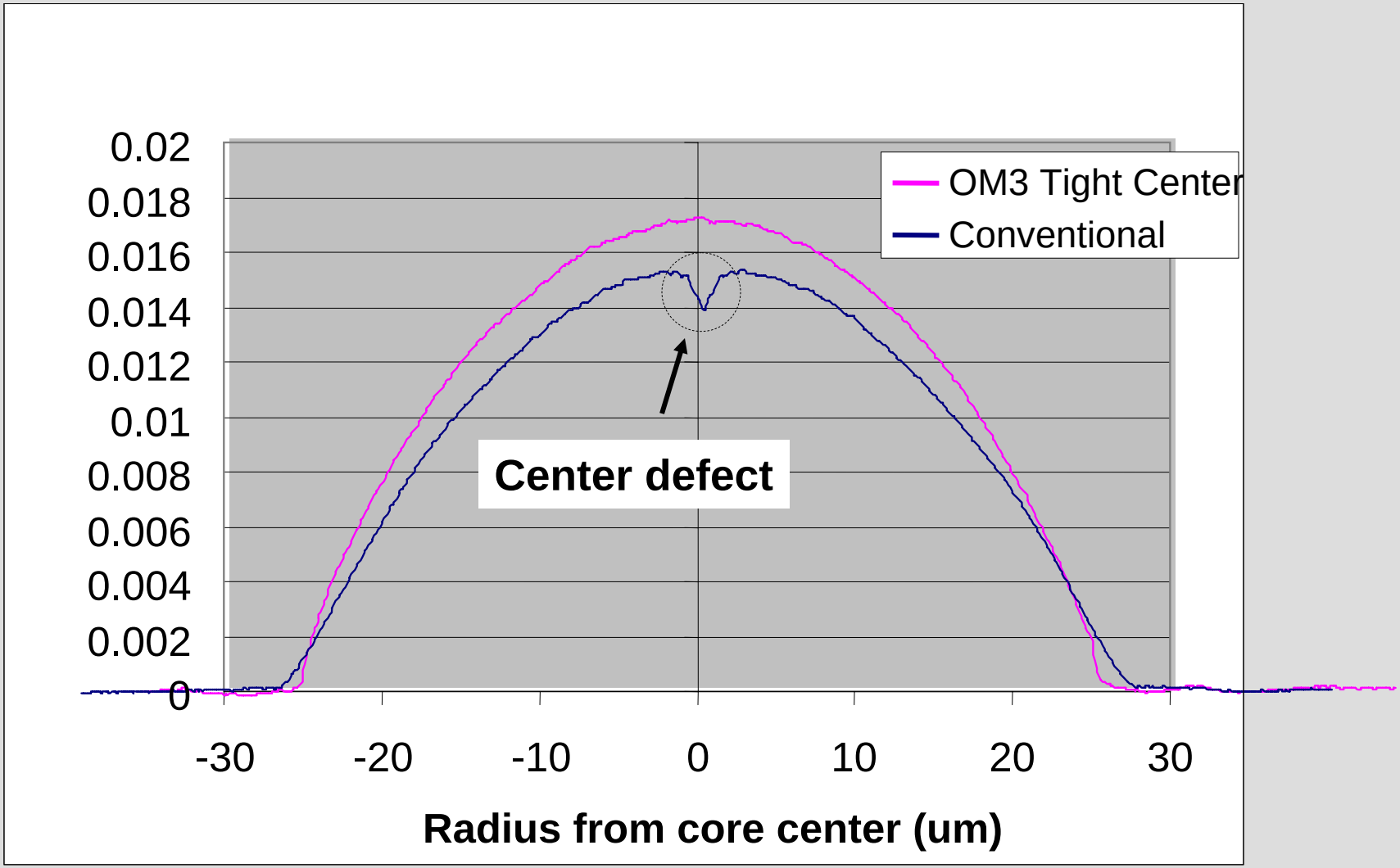
Mode Conditioning Patch Cords for conventional MMF

Required for 1000BASE-LX, 10GBASE-LX4 /LRM draft per IEEE 802.3



- **Shift power away from center defect in conventional MMF (FDDI, OM1, OM2)**
- **Laser transmits into singlemode fiber that is offset from MMF**
- Different cords for 50 and 62.5 micron
  - 50 micron – 10 to 16 micron offset
  - 62.5 micron – 17 to 23 micron offset
- About $300 each ($600 per link)

Laser Optimized 50 micron OM3 profile with tight center profile control eliminates center defect to avoid MCPC



10GBASE-LRM DRAFT IEEE standard
IEEE 802.3 Task Force "10G over FDDI MMF"

- **220 m original objective over 500 MHz-km "installed" MMF cables**
  - **FDDI 160/500 MHz-km**
  - **OM1 200/500 "**
  - **OM2 500/500 "**

- ***Customers pushed back on 220m objective***

- **300m in current draft for "installed" MMF**

  300m difficult on FDDI/OM1/OM2 fibers

  (conventional MMFs are not laser optimized)

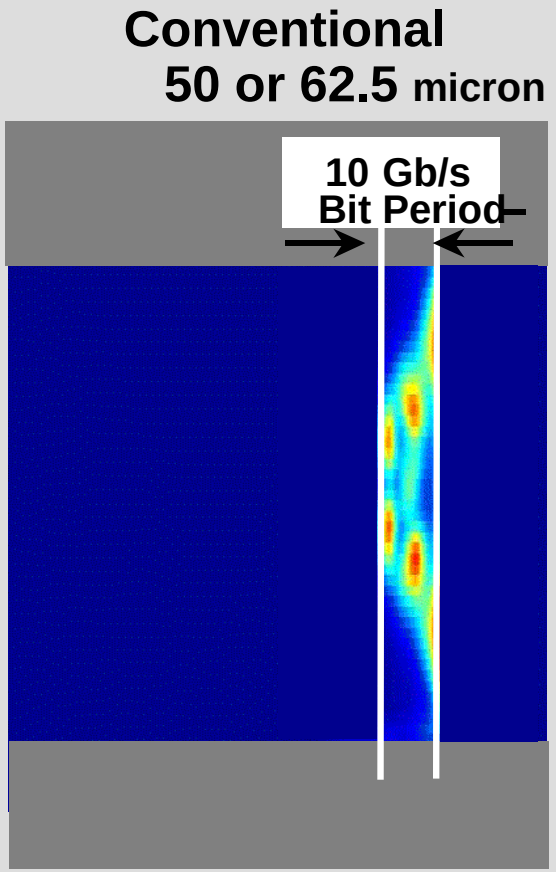
  - **TF direction: reduce coverage from IEEE precedent 99% of links at max distance to a lower percentage such as 95%.**

10GBASE-LRM DRAFT IEEE standard
IEEE 802.3 Task Force "10G over FDDI MMF"

- **300 meter objective over "selected" MMF cables**
  - **Laser Optimized 50 micron (2000/500 MHz-km)**
  - **No coverage/reliability issues expected for OM3**

10GBASE-LRM uses EDC in Receiver
(Electronic Dispersion Compensation)
Attempts to compensate for pulse spreading

- Analyses the received pulse
- Reduces ISI by discarding most power outside of bit period (up to 6 dB or more), but this incurs a large penalty.
- Can extend reach of MMF by ~3X
- Reliability suspect on conventional MMF
  - Installed base has huge variation in DMD, not designed for Lasers
- Expected to be more reliable on LO 50 micron fiber (OM3)



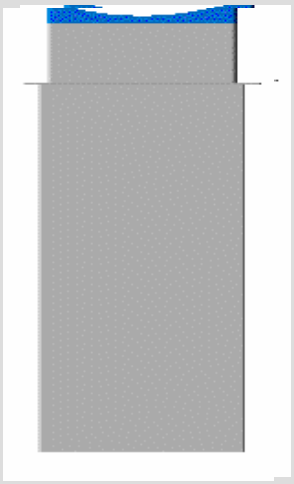
Why LRM when LX4 supports the same application?

Because LRM is expected to fit into compact XFP modules

SC

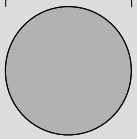
XENPAK
SR, LR, LX4

LC or SC

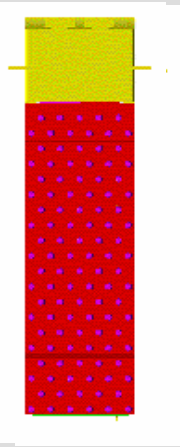


XPAK/X2
SR, LR, LX4

~1 inch



LC



XFP
SR easy,
LR, LRM OK,
LX4 difficult

10 Gigabit Ethernet LRM Draft standard

IEEE Task Force 802.3aq draft – SUBJECT TO CHANGE

From IEEE 802.3

10GBASE-LRM ***(Publication Scheduled for 2006)***

Description	62.5 μm MMF		50 μm MMF			Unit
Wavelength	1300					nm
Fiber Type	FDDI	OM1	OM2	OM2	**OM3**	
Modal bandwidth (min)	500	500	400	500	**500**	MHz-km
Operating Distance (max)	300	300	240	300	**300**	meters

LO-50 micron (OM3) fiber:

DOES NOT require mode conditioning patch cord

All other MMFs (conventional)

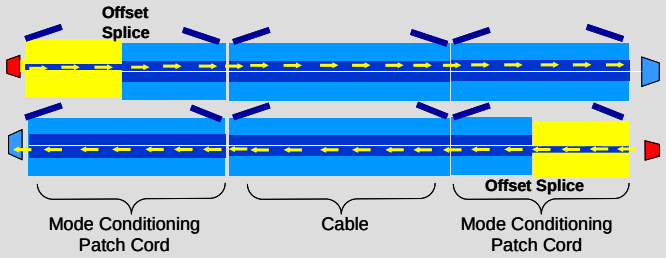
Mode conditioning patch cords REQUIRED per draft

- ~$600 per link – *ouch!*

10GBASE-LRM module cost

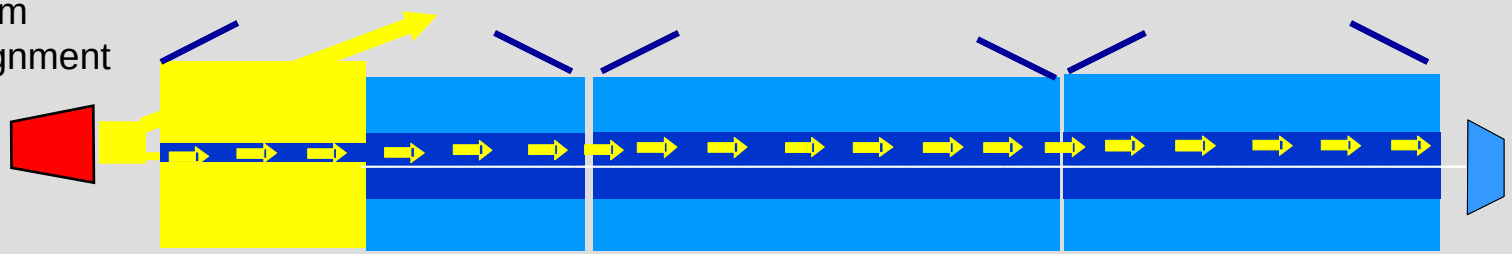
Cost expected to equal 10GBASE-LR singlemode module

10GBASE-LRM 1310 nm 220 – 300m MMF



Requires SM tolerances to couple into SMF in mode conditioning patch cord

Laser
2 - 3 um
misalignment



Offset Splice

Expensive Laser to Core Alignment = **+/- 1 micron**

- Costly materials and alignment during packaging
- Special glass optical lenses
- Hermetically sealed package

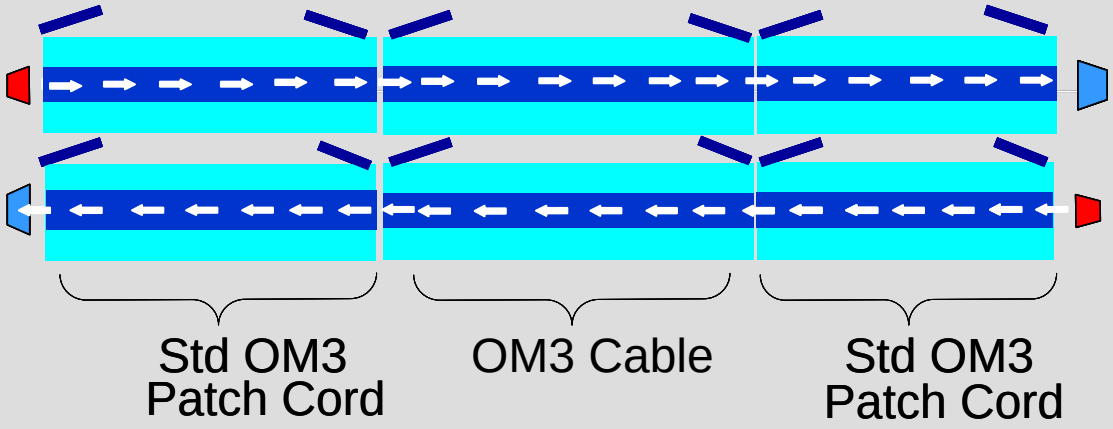
10GBASE-LRM DRAFT Standard – OM3 (LO-50 micron)

Uses standard patch cord to achieve highly reliable link

Launch for OM3 fiber

Standard Patch Cord at BOTH ends of link

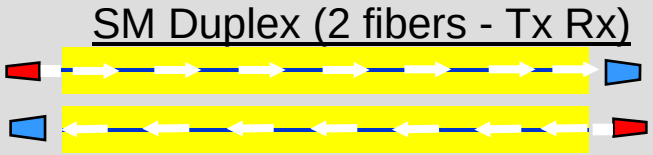
- **No patch cord experiments required by end user**
- **Saves ~$500 by avoiding mode conditioning cords**

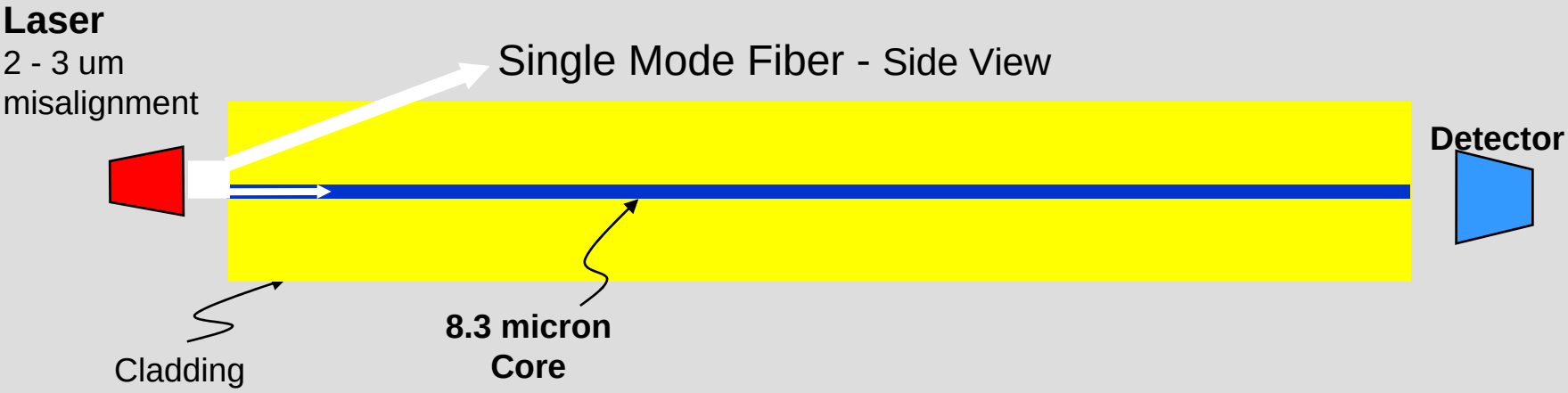


10GBASE-LR Singlemode Fiber Solution

Higher cost, best suited for >550 meter applications

10GBASE-LR	**1310 nm**	**10 KM**
10BBASER-ER	**1550 nm**	**40 KM**





Expensive Laser to Core Alignment = **+/- 1 micron**

- Costly materials and alignment during packaging
- Special glass optical lenses
- Hermetically sealed package
- Expensive single mode connectors and cabling installation

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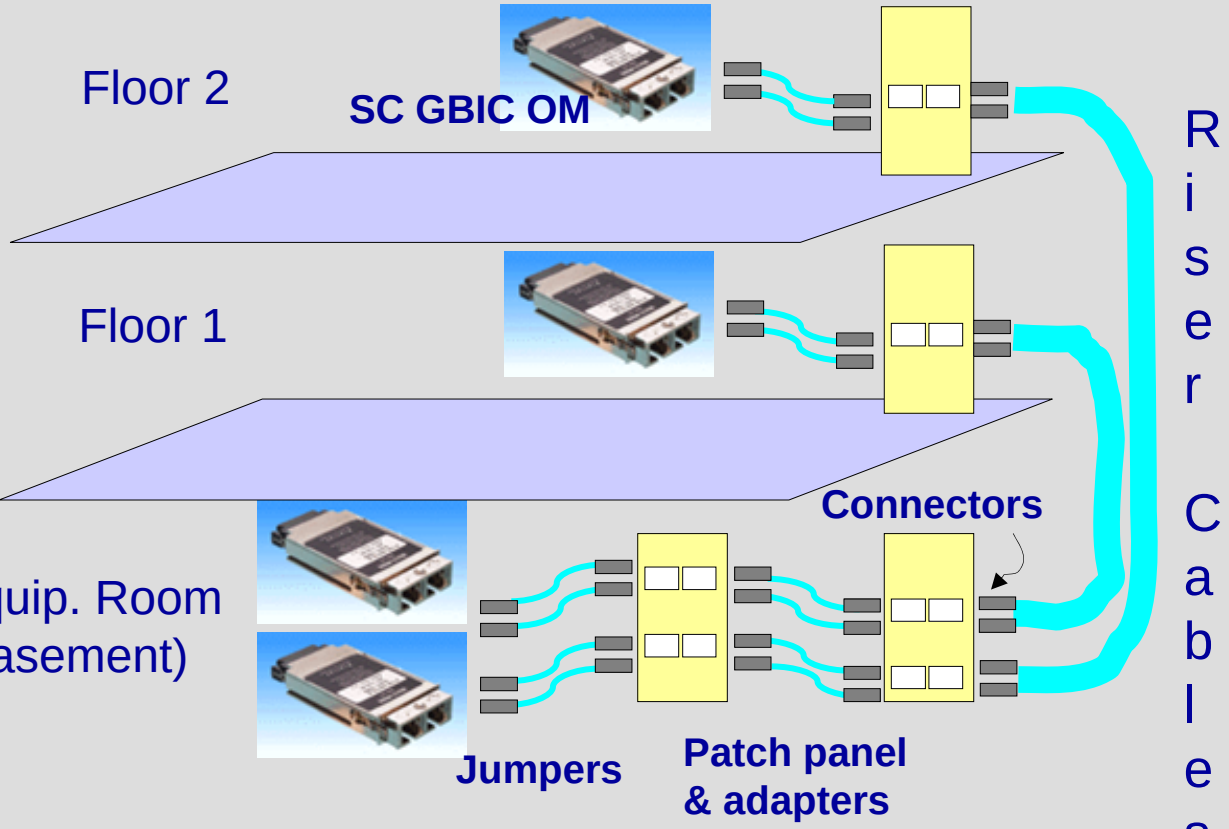
Optical System Cost Comparison

Building Backbone

Optical System Only
- Optical Modules
- Optical Cabling system
- Does not include switch

Cabling System
- Riser cables
- Patch panels, adapters
- Jumpers and connectors
- Typical backbone

Optical Modules (OM)
- Pluggable
- 2 or more per switch.
- 1 Gb/s and 10 Gb/s
- 850 nm MMF, 1310 SMF
- User selects based on reach and data rate



LC SFP (small form pluggable) OM

Optical System Cost Comparison

Assumptions – Optical Module Market Pricing

- 1 Gigabit in 2005 –
  - **850 nm (SX) $330 1310 nm (LX) $700**
- 10 Gigabit in 2005 –
  - **850 nm (SR) $1800 1310 nm (LR) $2,700, CWDM (LX4) $2,850**

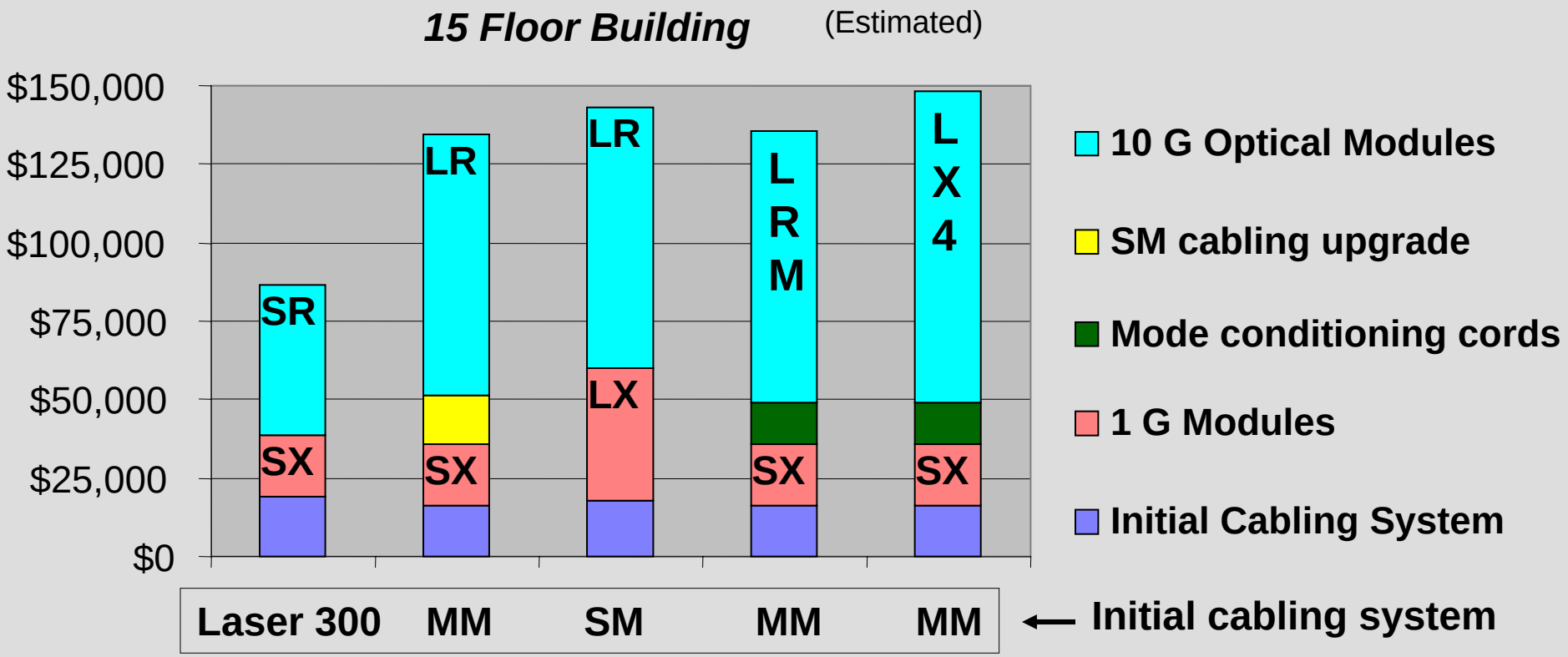
  source: 2/2005 OFS price survey of vendor prices

- 10 Gigabit in 2008
  - **850 nm (SR) $800 1310 nm (LR) $1385 LRM $1435 LX4 $1655**

  source: OFS projection

Optical System Cost Comparison

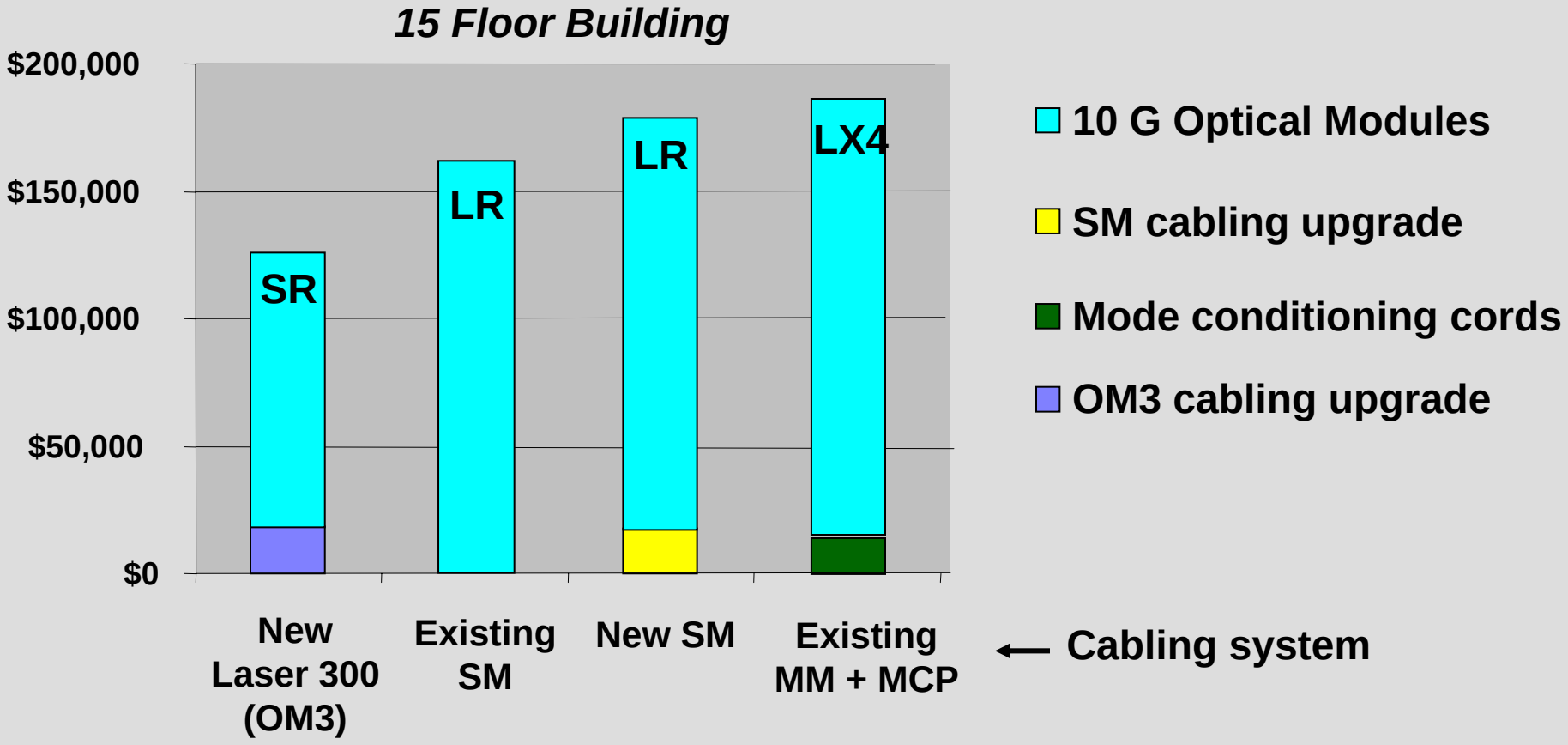
Building Backbone – 1G in 2005, upgrade to 10G in 2008



Laser 300 (OM3) Fiber based system saves $48K – $62K in this example

Optical System Cost Comparison

Building Backbone – upgrade to 10G in 2005



Pulling new Laser 300 (OM3) Fiber and running 10GBASE-SR saves $40K – $55K in this example

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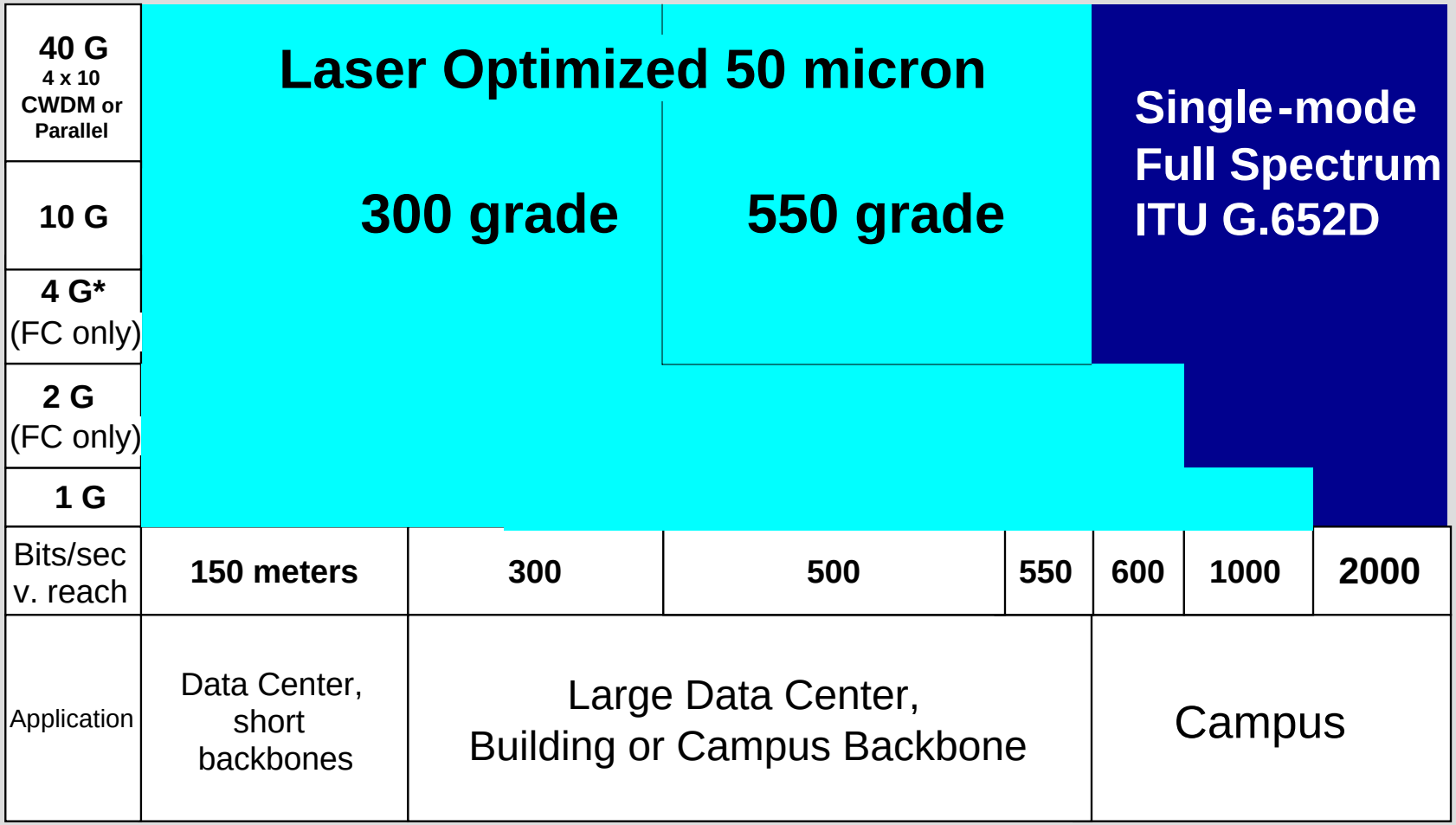
Recommended fibers for Ethernet and Fiber Channel

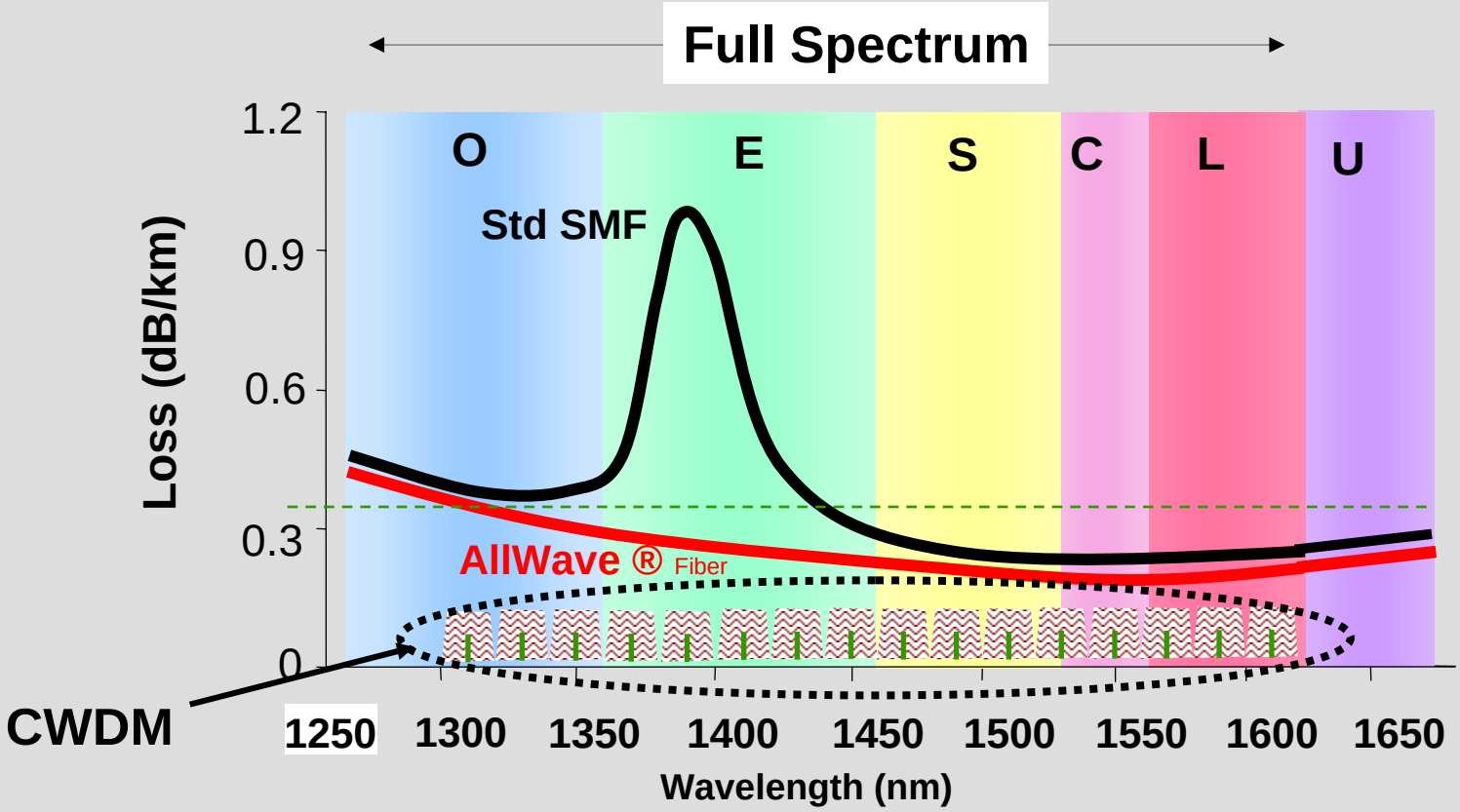
Low cost 850 nm serial on LO MMF (OM3 fiber) up to 550m - 1 KM



* Assumes improved specifications for laser spectral width and encircled flux likely in production transceivers

Zero-Water Peak Singlemode Fiber

Recommended for >550 - 1000 meter applications



No attenuation increase in E-band = 50% more bandwidth than conventional SMF

Enables Full Spectrum CWDM : 16 Wavelengths @ 20 nm spacing

G.652D compliant

The standard for new campus, access and metro deployments

10 Gigabit Ethernet over Multimode Fiber

Conclusion

New Installations

- **Laser Optimized 50 micron (OM3) recommended**
  - **30 – 50% lower system cost for 1G initial plus 10GSR upgrade**
  - **Lower cost for LRM and LX4 by eliminating MC patch cords.**
  - **Upgrade path to 40G using CWDM plus EDC**

10G upgrades to existing network links

- **Re-cable with LO- 50 micron (OM3) + SR for 25% - 35% lower cost**
- **If re-cabling prohibitively expensive:**
  - **Use existing fiber with LX4, LRM, or LR (SM only)**
- **SM (Full spectrum G.652D) for distances >550 meters**