



## HIGH BIT RATE OPTICAL FIBRE NETWORKS

prepared and delivered  
by



The  
Cabling  
Partnership


FIA Breakfast Seminar  
22nd March 2000  
9.15 - 11.30



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# The Cabling Partnership




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The Fibreoptic Industry Association

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- ├── Training
- ├── Design and specification
- ├── Cabling and IT cost management
- ├── Project management
- └── Audits and arbitration

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## Mike Gilmore



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Standards

**UK**

- Fibreoptic Industry Association, Technical Director
- BSI, Chairman, TCT7/-/1: IT Cabling

PD1001: "EMC and Structured Cabling"  
BS 7718: CoP "Installation of Fibre Optic Cabling"

**Europe**

- CENELEC, Convenor, TC215 WG1: IT Cabling


EN 50098-1: "ISDN Basic Access"  
EN 50098-2: "ISDN Primary Rate"  
EN 50173: "Generic - Design"  
prEN 50174: "Installation"  
prEN 50xxx: "Testing of Installed Cabling"

**International**

- ISO/IEC, Member, JTC1 SC25 WG3: Generic Cabling

ISO/IEC 11801: "Generic - Design"  
ISO/IEC 14763-1: "Administration"  
ISO/IEC TR14763-2: "Planning and Installation"  
ISO/IEC TR14763-3: "Testing Optical Cabling"  
and via IEC SC46A WG2  
IEC 61935: "Testing Copper Cabling"


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## Agenda



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**Session One**

Reviewing the basics

Designing  
attenuation-limited  
networks

Attenuation-limited  
LAN systems

Break

**Session Two**


Designing  
bandwidth-limited  
networks

Bandwidth-limited  
LAN systems

Multi-Gigabit applications

End


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# Agenda



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Session One

Reviewing the basics


Designing attenuation-limited networks

Attenuation-limited LAN systems

Break

**MMF: Multimode optical fibre**  
**SMF: Singlemode optical fibre**  
**MM optical fibre**  
**MMF performance options**  
**Connecting hardware options**


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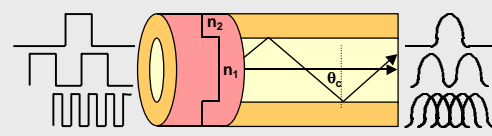
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# MMF: Multimode optical fibre

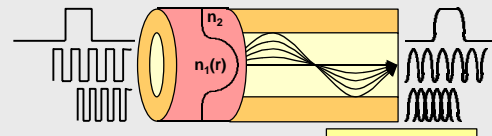


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**STEP (PED) INDEX (S.I.) MMF**

- path lengths: maximum variation
- path times: maximum variation
- bandwidth: modal dispersion



**GRADED INDEX (G.I.) MMF**

- path lengths: significant variation
- path times: limited variation
- bandwidth:
  - 1st order: modal dispersion
  - 2nd order: chromatic dispersion

Geometry options

d/D	NA
50/125	0.20
62.5/125	0.275

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## SMF: Singlemode optical fibre

**STEP (PED) INDEX (S.I.) SMF**

- path lengths: no variation
- path times: no variation
- bandwidth:
  - 1st order: chromatic dispersion
  - 2nd order: pulse shape dispersion

Geometry	
d/D	NA
8-10/125	0.10

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## MM optical fibre

Optical fibre geometry (standardized)				
	50/125		62.5/125	
Core diameter (µm)	50 ± 3		62.5 ± 3	
Cladding diameter (µm)	125 ± 3		125 ± 3	
NA	0.20 ± 0.015		0.275 ± 0.015	

Optical fibre performance parameters (options)			
Attenuation coefficient dBkm <sup>-1</sup> max.		Modal bandwidth MHz.km min.	
850nm	1300nm	850nm	1300nm
?	?	?	?


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## MMF performance options




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	Attenuation coefficient dBkm <sup>-1</sup> max.		Modal bandwidth MHz.km min.		
	850nm	1300nm	850nm	1300nm	
50/125 and 62.5/125	3.5	1.0	200	500	ISO/IEC 11801 and EN 50173 (1995)
62.5/125	3.75	1.5	160	500	ANSI/TIA/EIA 568A (1995)
50/125	3.5	1.5	500	500	ISO/IEC 11801 and EN 50173 (2001)
62.5/125	3.5	1.5	200	500	ISO/IEC 11801 and EN 50173 (2001)

	Attenuation coefficient dBkm <sup>-1</sup> max.		Modal bandwidth MHz.km min.			
	850nm	1300nm	850nm	1300nm	850nm	1300nm
50/125	2.4	0.6	400	400	200	400
	2.5	0.8	400	600	200	600
	2.7	1.0	400	800	160	200
62.5/125	3.0	0.7	400	1000	200	200
	3.2	0.9	400	1200	250	1000
			400	1500	300	800
		600	1000			


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## Connecting hardware options



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SPLICES		Insertion loss (max.)		Return loss	
		Singlemode/multimode		Singlemode	Multimode
ISO/IEC 11801 and EN 50173 (1995/2001)		100% < 0.30 dB		-	-

DEMOUNTABLE CONNECTING HARDWARE: INTEROPERABILITY STANDARDS					
		Insertion loss (max.)		Return loss	
		Singlemode/multimode		Singlemode	Multimode
TO in ISO/IEC 11801 and EN 50173 (1995)	ST (BFOC2,5): MMF	IEC 60874-10		26dB	20dB
	SC-D (duplex): MMF	IEC 60874-19-1			
TO in ISO/IEC 11801 and EN 50173 (2001)	SC-D (duplex): MMF	IEC 60874-19-1		95% < 0.5 dB, 100% < 0.75 dB	35dB


DEMOUNTABLE CONNECTING HARDWARE: ALTERNATIVE INTERFACE STANDARDS					
Interoperability not guaranteed by standards					
F-SMA, CF-03, CF-04, BAM, LSA, FC, D, OF-2, OCCA-PC, OCCA-BU, CF-08, SC, DS, F-05, MU, MPO			SFF types in preparation: LC, SG (Volition), MT-RJ		

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# Agenda



Session One

Reviewing the basics

Designing attenuation-limited networks

Attenuation-limited LAN systems

Break


Optical power budget (OPB)  
Optical loss budget (OLB)  
Attenuation-limited systems

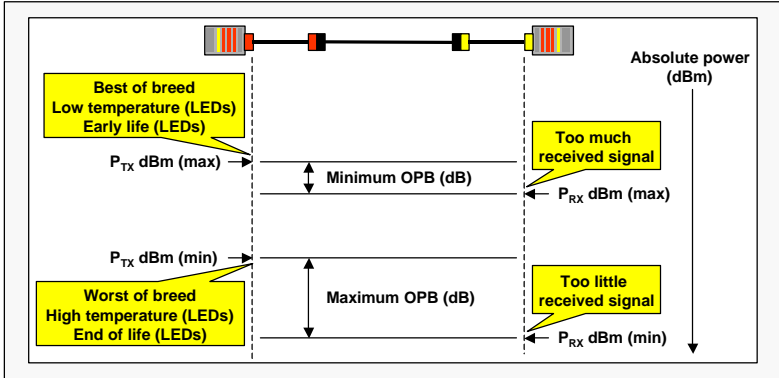
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# Optical power budget (OPB)






The diagram illustrates an optical fiber link between a transmitter and a receiver. The transmitter side shows two power levels:  $P_{Tx} \text{ dBm (max)}$  (Best of breed, Low temperature LEDs, Early life LEDs) and  $P_{Tx} \text{ dBm (min)}$  (Worst of breed, High temperature LEDs, End of life LEDs). The receiver side shows two power levels:  $P_{Rx} \text{ dBm (max)}$  (Too much received signal) and  $P_{Rx} \text{ dBm (min)}$  (Too little received signal). The vertical axis represents Absolute power (dBm). The horizontal distance between the transmitter and receiver is divided into two regions: Minimum OPB (dB) and Maximum OPB (dB).

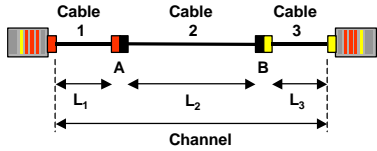
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## Optical loss budget (OLB)





Optical loss budget: limits of calculated channel attenuation

In the example:  
 $OLB_{min} = L_1 \alpha_{(Cable\ 1)} + L_2 \alpha_{(Cable\ 2)} + L_3 \alpha_{(Cable\ 3)} + loss_A + loss_B$  (dB) using min. values  
 $OLB_{max} = L_1 \alpha_{(Cable\ 1)} + L_2 \alpha_{(Cable\ 2)} + L_3 \alpha_{(Cable\ 3)} + loss_A + loss_B$  (dB) using max. values


In general:  
 $OLB_{min} = \sum \alpha_{(Cable\ i)} \times L_i + \sum connectors/splices$  (dB) using minimum values  
 $OLB_{max} = \sum \alpha_{(Cable\ i)} \times L_i + \sum connectors/splices$  (dB) using maximum values

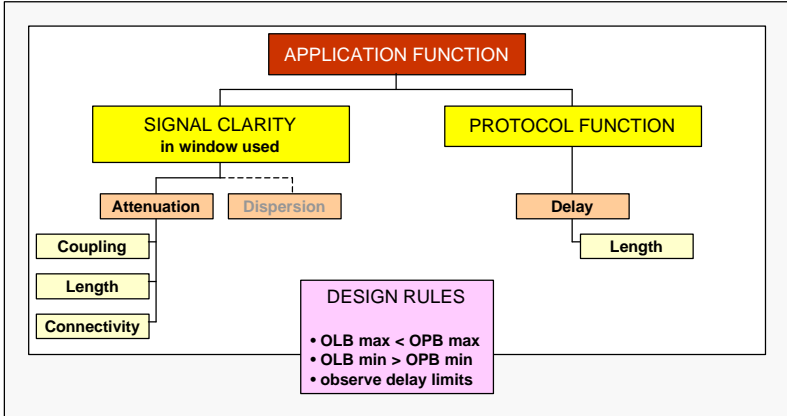
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## Attenuation-limited systems





DESIGN RULES

- $OLB_{max} < OPB_{max}$
- $OLB_{min} > OPB_{min}$
- observe delay limits

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**Session One**


Reviewing the basics

Designing attenuation-limited networks

Attenuation-limited LAN systems

Break


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## Attenuation-limited LAN standards



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		50/125		62.5/125		OPB Δ (dB)
		Max. length (m)	OPB max. (dB)	Max. length (m)	OPB max. (dB)	
850 nm	ISO/IEC 8802-3: FOIRL	514 <sup>1</sup>	3.3	1000	9.0	5.7
	ISO/IEC 8802-3: 10BASE-FL/FB	1514 <sup>1</sup>	6.8	2000	12.5	5.7
	ISO/IEC TR 11802-4: 4 & 16 Mb/s Token Ring	1857 <sup>1</sup>	8.0	2000	13.0	5.0
	IEEE 802.12: Demand priority	371 <sup>1</sup>	2.8	500	7.5	4.7
1300 nm	ISO/IEC 9314-3: FDDI PMD	2000	6.0	2000	11.0	5.0
	ISO/IEC 8802-3: 100BASE-FX	2000	6.0	2000	11.0	5.0
	IEEE 802.12: Demand priority	533 <sup>1</sup>	2.3	2000	7.0	4.7
	ATM @ 52 Mb/s	2000	5.3	2000	10.0	4.7
	ATM @ 155 Mb/s	2000	5.3	2000	10.0	4.7

<sup>1</sup> Calculated values using 1.5dB of connecting hardware losses

**62.5/125 seems to offer advantages**

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**Session One**

- Reviewing the basics
- Designing attenuation-limited networks
- Attenuation-limited LAN systems
- Break

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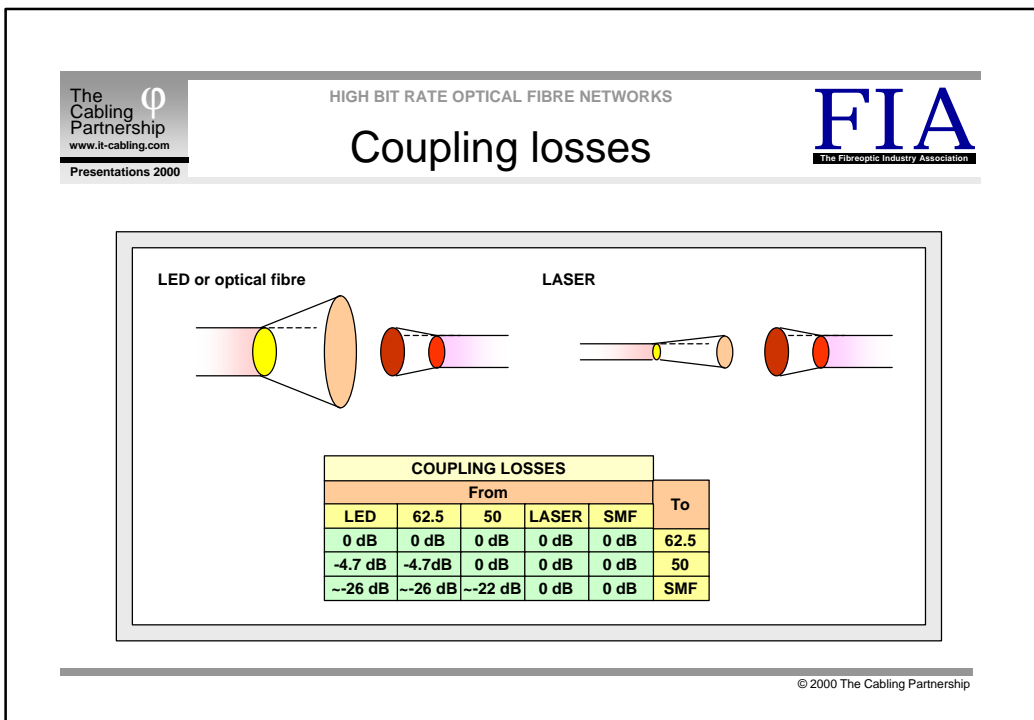
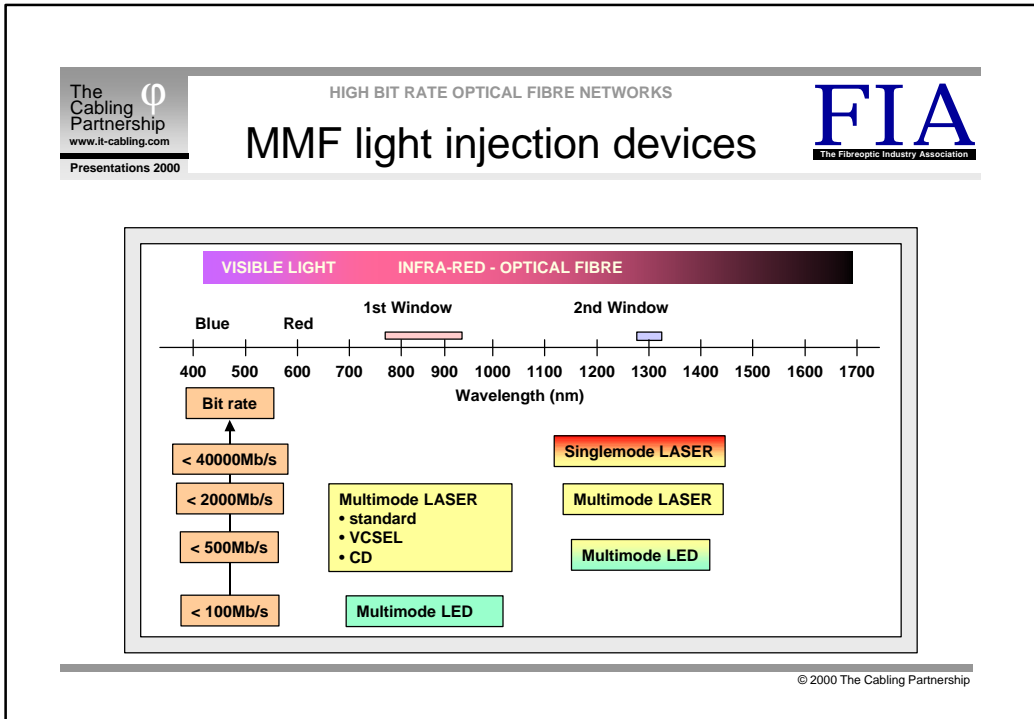
# Agenda

**Session Two**

- Designing bandwidth-limited networks
- Bandwidth-limited LAN systems
- Multi-Gigabit applications
- End

**MMF light injection devices**  
Coupling losses  
OPB-based cabling design  
Channel length equations  
Modal bandwidth  
Bandwidth-limited technology  
Bandwidth-limited systems


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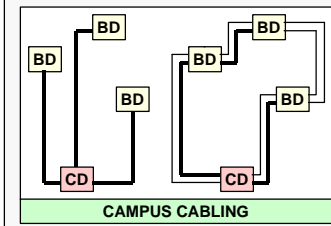


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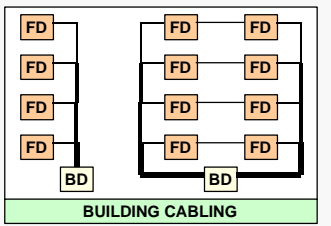
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## OPB-based cabling design





**CAMPUS CABLING**



**BUILDING CABLING**


Maximum channel length = (OPB - total connection loss)/cable attenuation

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## Channel length equations



		50/125		62.5/125	
		CAP	Channel length (m)	CAP	Channel length (m)
850 nm	ISO/IEC 8802-3: FOIRL	-	940 - 142x - 85y	1000	2570 - 142x - 85y
	ISO/IEC 8802-3: 10BASE-FL/FB	-	1940 - 142x - 85y	2000	3570 - 142x - 85y
	ISO/IEC TR 11802-4: 4 & 16 Mb/s Token Ring	2000	2285 - 142x - 85y	2000	3710 - 142x - 85y
	IEEE 802.12: Demand priority	500	800 - 142x - 85y	500	2140 - 142x - 85y
1300 nm	ISO/IEC 9314-3: FDDI PMD	2000	4000 - 333x - 200y	2000	7330 - 333x - 200y
	ISO/IEC 8802-3: 100BASE-FX	2000	4000 - 333x - 200y	2000	7330 - 333x - 200y
	IEEE 802.12: Demand priority	800	1530 - 333x - 200y	2000	6665 - 333x - 200y
	ATM @ 52 Mb/s	2000	3530 - 333x - 200y	2000	6665 - 333x - 200y
	ATM @ 155 Mb/s	2000	3530 - 333x - 200y	2000	6665 - 333x - 200y
x = no. of mated connectors @ 0.5dB y = no. of splices @ 0.3dB					


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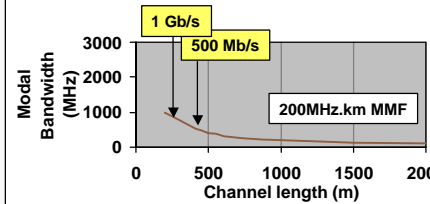
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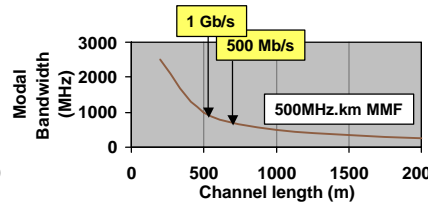
## Modal bandwidth



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200MHz.km MMF



500MHz.km MMF

	Attenuation coefficient dBkm <sup>-1</sup> max.		Modal bandwidth MHz.km min.		
	850nm	1300nm	850nm	1300nm	
50/125 and 62.5/125	3.5	1.0	200	500	ISO/IEC 11801 and EN 50173 (1995)
62.5/125	3.75	1.5	160	500	ANSI/TIA/EIA 568A (1995)
50/125	3.5	1.5	500	500	ISO/IEC 11801 and EN 50173 (2001)
62.5/125	3.5	1.5	200	500	ISO/IEC 11801 and EN 50173 (2001)


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## Bandwidth-limited technology



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**Historic applications have channel lengths defined by OPB**

- OPB > calculated bandwidth for distances supported

**New applications use data rates for which bandwidth requirements define channel lengths**

- longer lengths cannot be guaranteed even if low attenuation channels are used

**Modal bandwidths have rarely been specified by users/installers**

**Modal bandwidth difficult/impossible to measure on-site**

- bandwidth-limited applications are installed with higher risk

**Higher data rates utilise LASER technologies**

- CD LASERS, VCSELs and standard LASERS

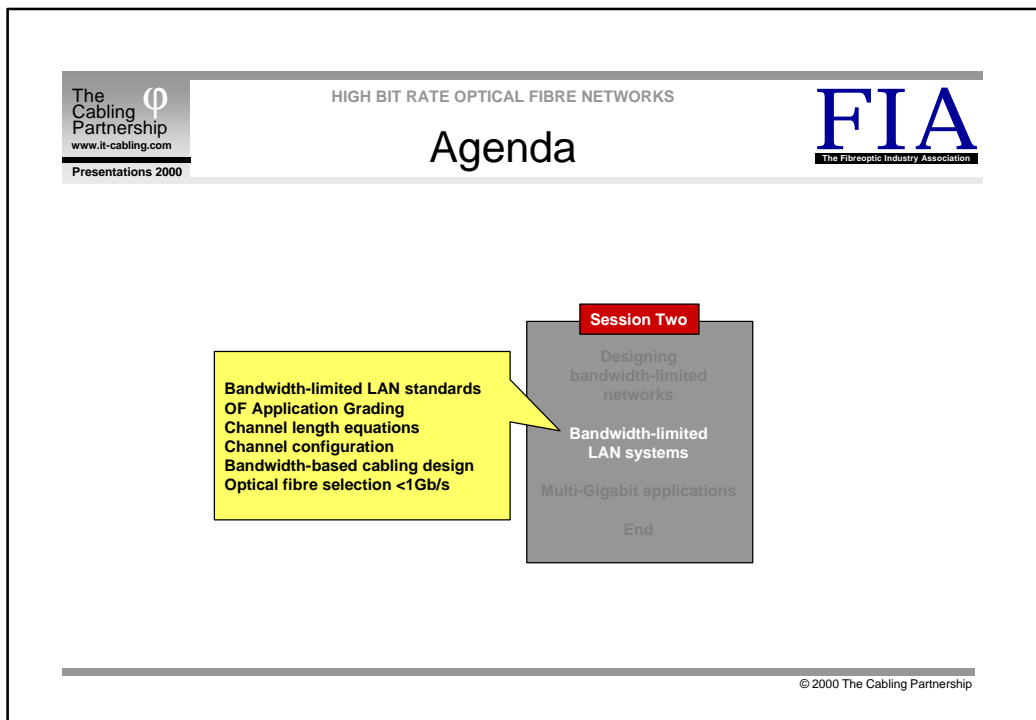
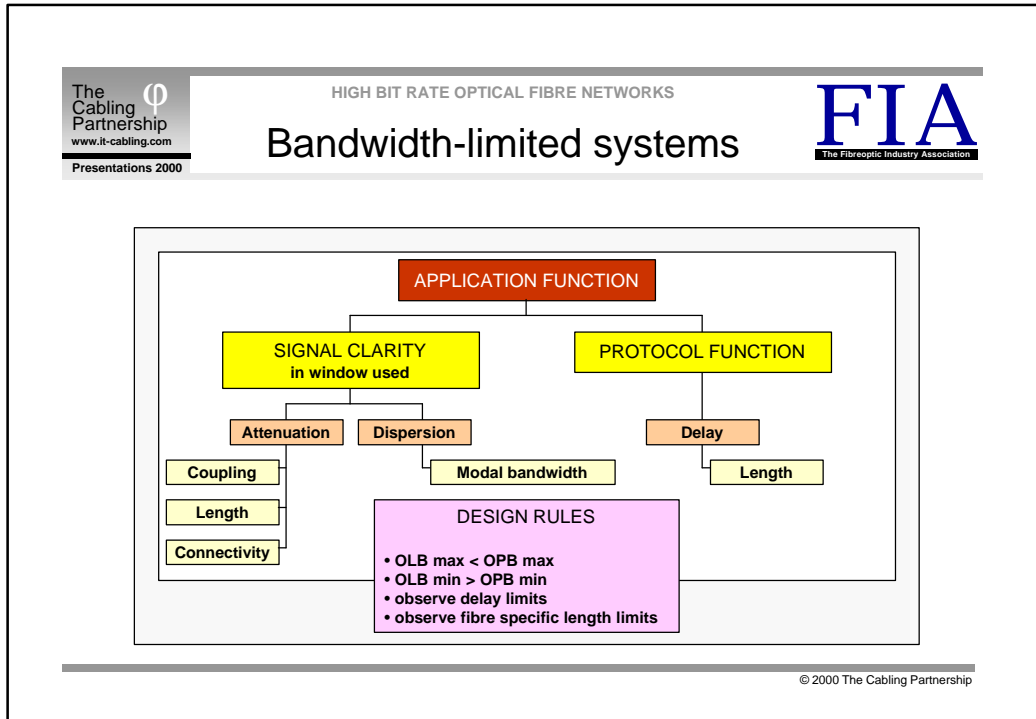
- reductions in OPBs due to restricted power input/channel lengths


**Optical fibre modal bandwidth measured using LED launch conditions**

- LASER sources should provide improved bandwidth
- some problems found with RI profiles

**OPTICAL FIBRE SELECTION AND CONFIGURATION IMPACTED**

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## Bandwidth-limited LAN standards



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		50/125 500/500MHz.km		62.5/125 200/500MHz.km		OPB Δ (dB)
		Max. length (m)	OPB max. (dB)	Max. length (m)	OPB max. (dB)	
850 nm	ATM @ 155 Mb/s	1000	7.2	1000	7.2	0.0
	CD 14165: FibreChannel @ 266 Mb/s	2000	12.0	700	12.0	0.0
	CD 14165: FibreChannel @ 531 Mb/s	1000	8.0	350	8.0	0.0
	ATM @ 622 Mb/s	300	4.0	300	4.0	0.0
	IEEE 802.3: 1000BASE-SX: Gigabit Ethernet	550	3.56	275	2.6	-0.96
	CD 14165: FibreChannel @ 1062 Mb/s	500	4.0	300	4.0	0.0
1300 nm	CD 14165: FibreChannel @ 133 Mb/s	371 <sup>1</sup>	1.3	1500	6.0	4.7
	CD 14165: FibreChannel @ 266 Mb/s	2000	5.5	1500	6.0	0.5
	ATM @ 622 Mb/s	330	2.0	500	6.0	4.0
	IEEE 802.3: 1000BASE-LX: Gigabit Ethernet	>550	2.35	550	2.35	0.0

<sup>1</sup> Assuming no connecting hardware loss

50/125 seems to offer advantages


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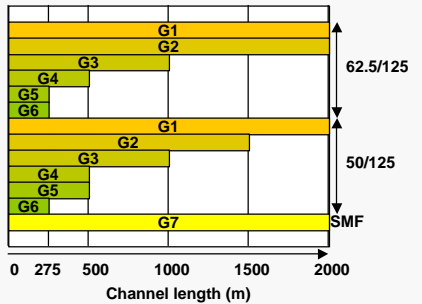
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## OF Application Grading



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	MMF	SMF	
G1	Token Ring 100BASE-FX FDDI ATM52 (1300) ATM155 (1300)	FDDI ATM52 (1310) ATM155 (1310)	
G2	10BASE-FL 10BASE-FB		
G3	ATM155 (850)		
G4	1000BASE-LX ATM622 (1300)*	1000BASE-LX ATM622 (1310)	
G5	1000BASE-SX		
G6	ATM622 (850)		

**KEY FEATURES**

- lengths shown assume 1.5dB connecting hardware loss
- G2 applications limited on 50/125
- G5 applications limited on 62.5/125
- not all applications supported on singlemode


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## Channel length equations




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		50/125 500/500MHz.km		62.5/125 200/500MHz.km	
		CAP	Channel length (m)	CAP	Channel length (m)
850 nm	ATM @ 155 Mb/s	2000	2085 - 142x - 85y	1000	2085 - 142x - 85y
	CD 14165: FibreChannel @ 266 Mb/s	2000	3425 - 142x - 85y	700	3425 - 142x - 85y
	CD 14165: FibreChannel @ 531 Mb/s	2000	2285 - 142x - 85y	350	2285 - 142x - 85y
	ATM @ 622 Mb/s	300	1140 - 142x - 85y	300	1140 - 142x - 85y
	IEEE 802.3: 1000BASE-SX: Gigabit Ethernet	550	1015 - 142x - 85y	275	740 - 142x - 85y
1300 nm	CD 14165: FibreChannel @ 1062 Mb/s	500	1140 - 142x - 85y	300	1140 - 142x - 85y
	CD 14165: FibreChannel @ 133 Mb/s	-	865 - 333x - 200y	1500	4000 - 333x - 200y
	CD 14165: FibreChannel @ 266 Mb/s	2000	3665 - 333x - 200y	1500	4000 - 333x - 200y
	ATM @ 622 Mb/s	300	1465 - 333x - 200y	500	4000 - 333x - 200y
	IEEE 802.3: 1000BASE-LX: Gigabit Ethernet	550	1565 - 333x - 200y	550	1565 - 333x - 200y

x = no. of mated connectors @ 0.5dB  
y = no. of splices @ 0.3dB


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## Channel configuration



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Reduce loss to a minimum for a given length

- do not use unnecessary connections



remember:

1 mated connection = 142 metres (@ 850 nm in MMF)  
= 333 metres (@ 1300 nm in MMF)

1 splice = 85 metres (@ 850 nm in MMF)  
= 200 metres (@ 1300 nm in MMF)

Consider splicing of pre-manufactured tails

- Lower overall loss than field terminations


Adopt cleaning procedures to minimise contamination losses

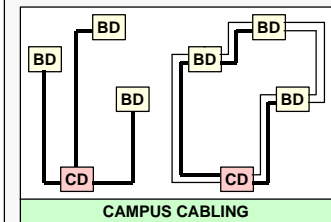
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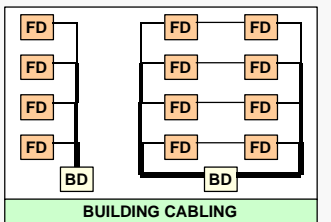
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## Bandwidth-based cabling design





**CAMPUS CABLING**



**BUILDING CABLING**


Maximum channel length = (OPB - total connection loss)/cable attenuation

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HIGH BIT RATE OPTICAL FIBRE NETWORKS


## Optical fibre selection <1Gb/s



	Max. OLB (dB)		Optical fibre choices	
	850 nm	1300 nm		
< 200 metres	2.3	1.3	Either 50/125 <sup>1</sup> or 62.5/125 <sup>2</sup>	
< 500 metres	3.3	2.3	50/125 <sup>1</sup>	SMF > 1Gb/s  SMF > 200Mb/s
< 1500 metres	6.8	6.0	50/125	
	12.0	10.0	62.5/125 <sup>3</sup>	
< 2000 metres	6.8	6.0	50/125	
	12.0	10.0	62.5/125 <sup>3</sup>	

<sup>1</sup> 50/125:	3.5/1.5dBkm <sup>-1</sup> , 500/500MHz.km
<sup>2</sup> 62.5/125:	3.5/1.5dBkm <sup>-1</sup> , 200/500MHz.km preferred
<sup>3</sup> 62.5/125:	3.5/1.5dBkm <sup>-1</sup> , 200/500MHz.km adequate


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HIGH BIT RATE OPTICAL FIBRE NETWORKS

# Agenda



FIA  
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Session Two


Designing bandwidth-limited networks

Bandwidth-limited LAN systems


Multi-Gigabit applications

End

10 Gb/s Ethernet: 802.3ae (03/02)  
Optical fibre developments




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HIGH BIT RATE OPTICAL FIBRE NETWORKS

# 10 Gb/s Ethernet: 802.3ae



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OBJECTIVES

- switched operation only
- star topology
- support link aggregation
- support 10Gb/s Ethernet and 9.584640Gb/s SONET
- 2000 m, 10000 m and 40000 m over SMF
- 100 m over existing MMF
- 300 m over "new" optical fibre @ 850nm

PROPOSALS

- legacy MMF
  - 850nm VCSELs: ~ 65 m
  - 850nm 4 x parallel optics: 300 m
  - 850nm PAM-5 coding: >100 m
  - 1300nm FP LASERS: > 100 m
  - 1300nm 4 x WWDM: 300 m
- enhanced MMF
  - 850nm VCSELs: 300 m
- legacy SMF
  - 1300nm LASERS: 300 m to 10000 m
  - 1550nm LASERS: 40000 m

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HIGH BIT RATE OPTICAL FIBRE NETWORKS

**Optical fibre developments**

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**PROPOSALS UNDERWAY**

50/125µm: 3.5/1.5dBkm<sup>-1</sup>, 2200/500MHz.km

Bandwidth measurement made using LASER launch conditions

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