Plastic Optical Fibres

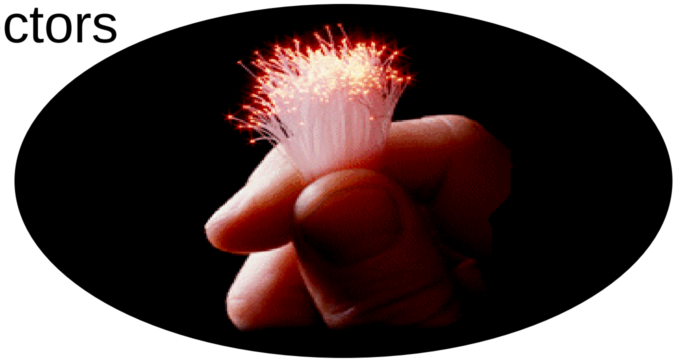
for Gigabit Networking

Overview

- POF overview and GI-POF
- Networking applications for GI-POF
- GI-POF product development status
- GI-POF demonstration projects, 2004

POF performance

- Compared with MMF, copper and wireless, POF offers the following advantages:
  - Ruggedness, flexibility, easy handling, simplified architecture
  - Availability of inexpensive all-plastic connectors
  - Reduction in installation cost
  - Free from EMI problems
  - The preference for consumer electronics
  - Stability (non-flammability and excellent chemical resistance)
  - Availability of low cost light source (LED, RCLED, VCSEL) from visible to near IR (650, 780, 850, 1300 nm) and high-speed detectors



Advantages of Plastic Optical Fibers (POF)


Razor blade cut
3 second dry polish

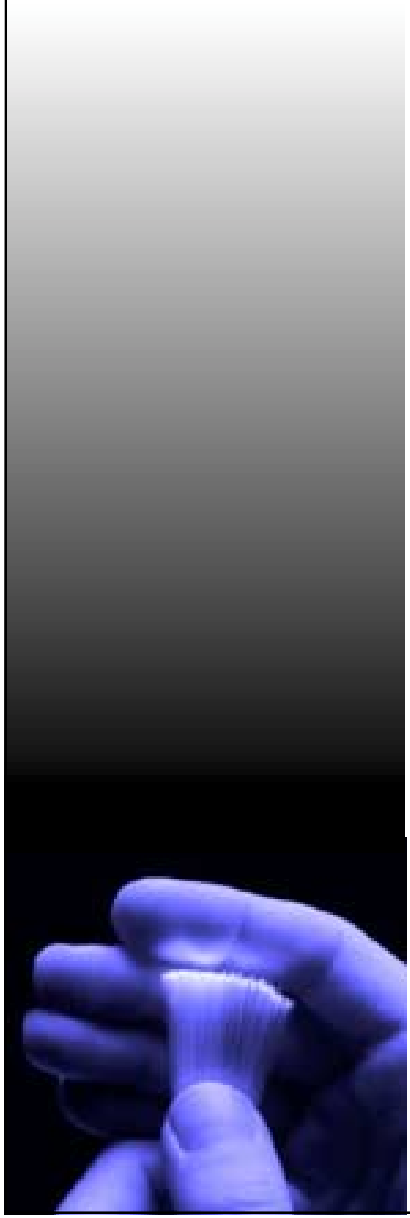
Ease of Installation

- No expensive termination tooling required
- Simple end preparation (5-10 second dry polish)
- Smaller installed bend radius allowed than silica fiber (non-brittle)
- Large core diameters are NOT important for POF in Gb/s applications

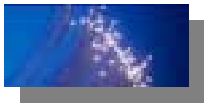
Performance

- High bandwidth over broad wavelength range (lower material dispersion than silica)
- Simple methods for increasing BW using restricted launch (10 Gb/s x 100m)
- Lower modal noise than multimode silica fibers
- Radiation hardness better than silica multimode fiber

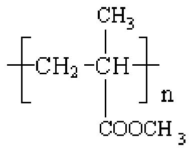
Materials: PMMA or CYTOP



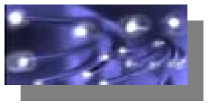
Two main materials for POF today:



PMMA (~ PLEXIGLAS)



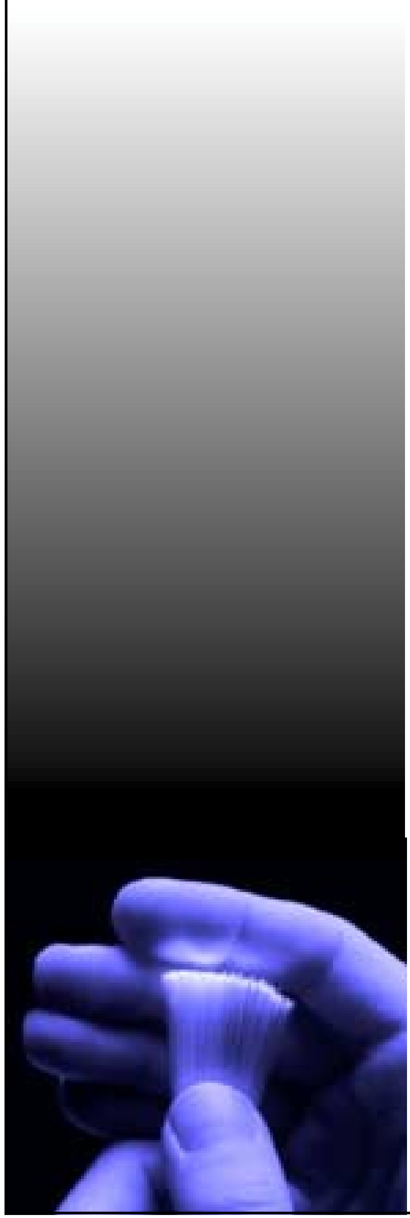
- CH based material
- Attenuation about 130 dB/km
- Operating mostly limited to 650
- Short link (up to 50 m)



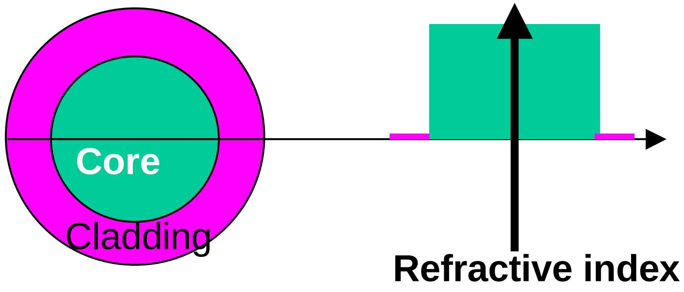
PERFLUORINATED (~ TEFLON AF, CYTOP)

- CF based materials
- Low attenuation (now down to 20 dB/km)
- Operating at 650, 850 & 1300 nm
- Long link (up to 1 km)

Two main fibre types : SI-POF or GI-POF

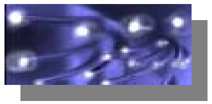


Step Index SI- POF

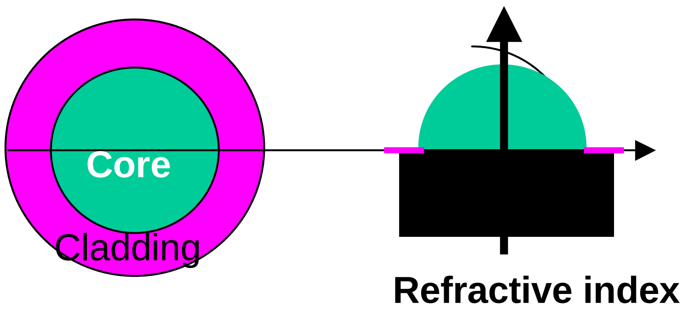


Demonstrated bit rate:

500 Mb/s (100m)



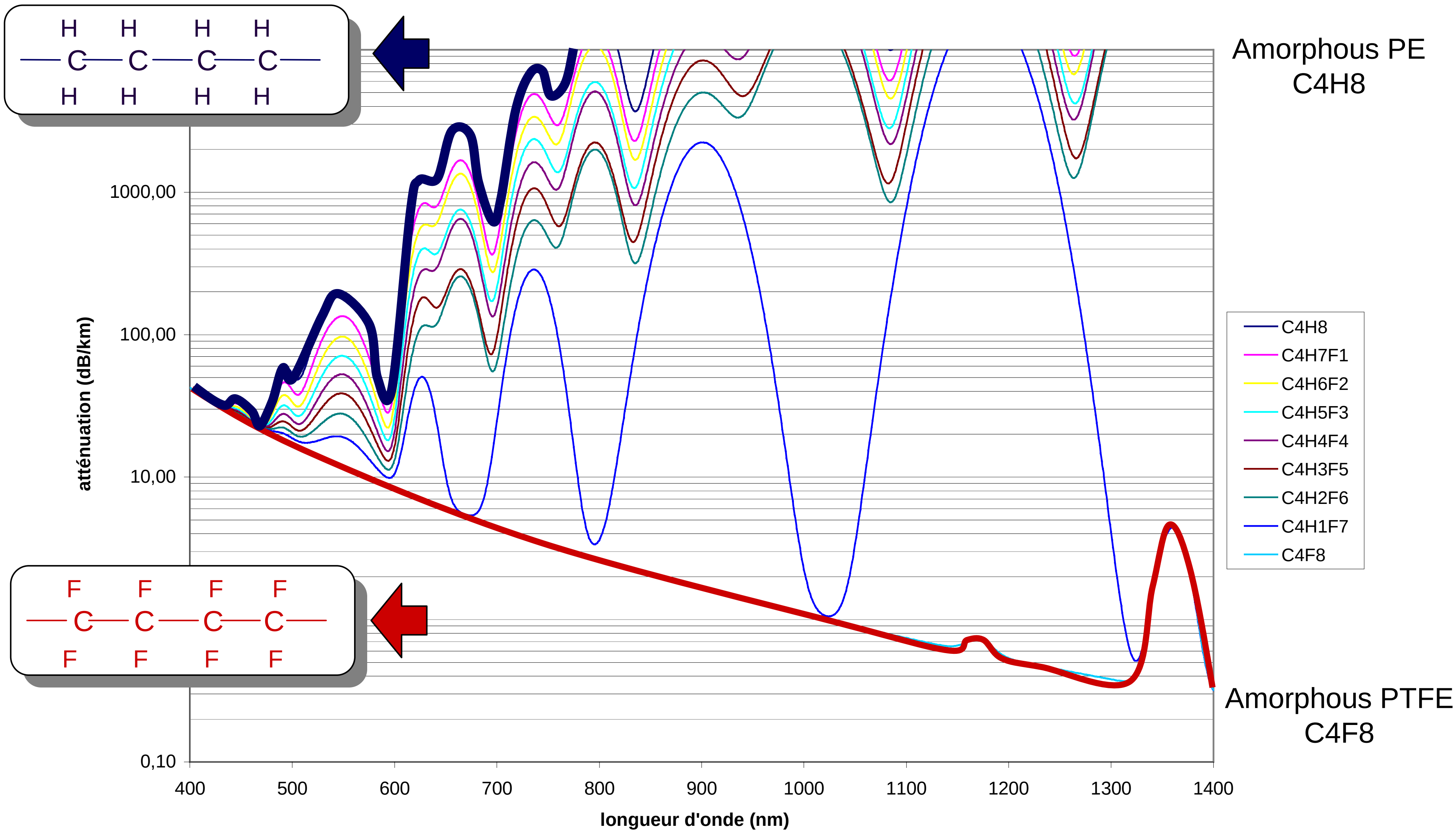
Graded Index GI-POF



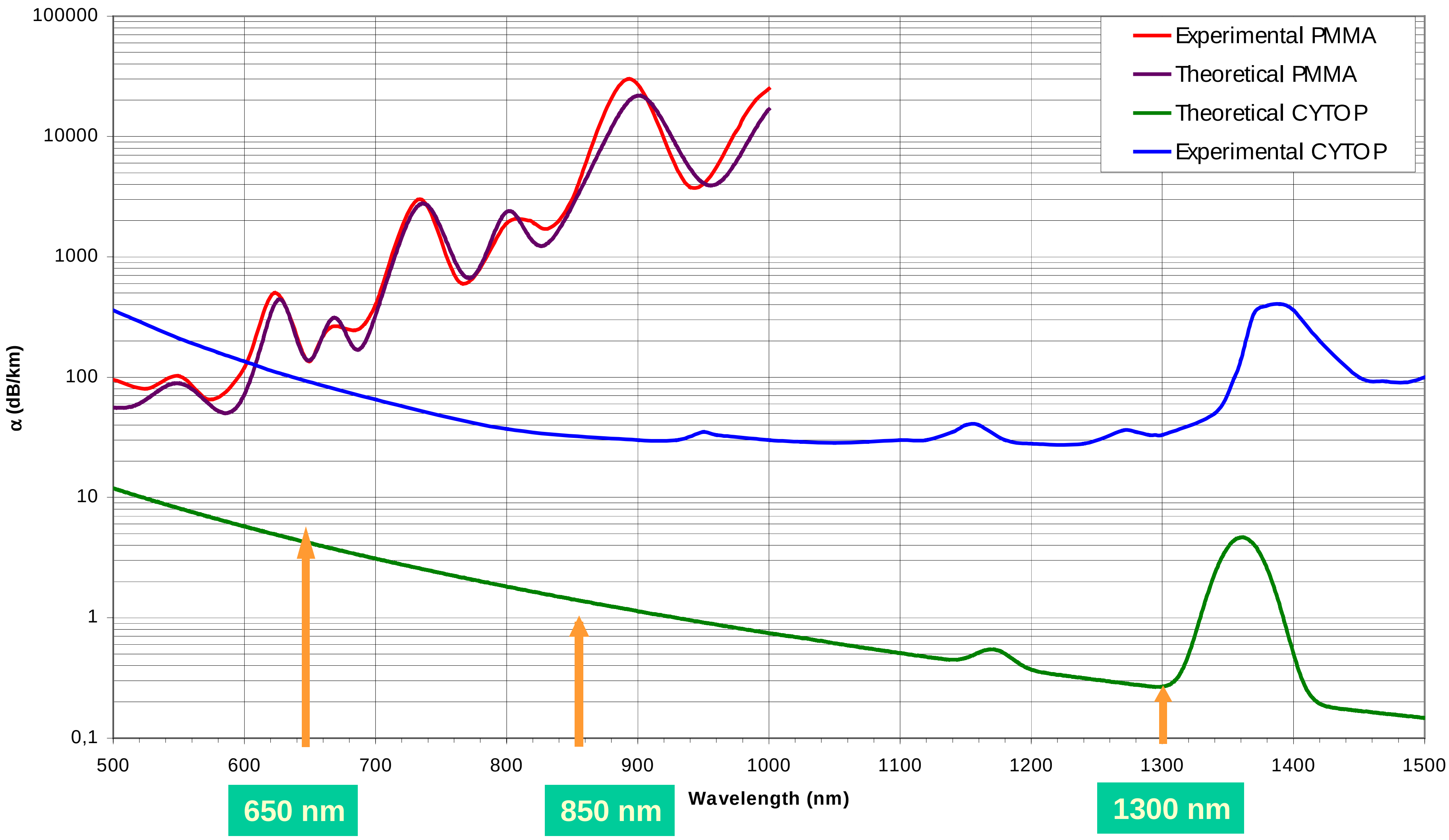
Demonstrated bit rate:

10 Gb/s (100m)

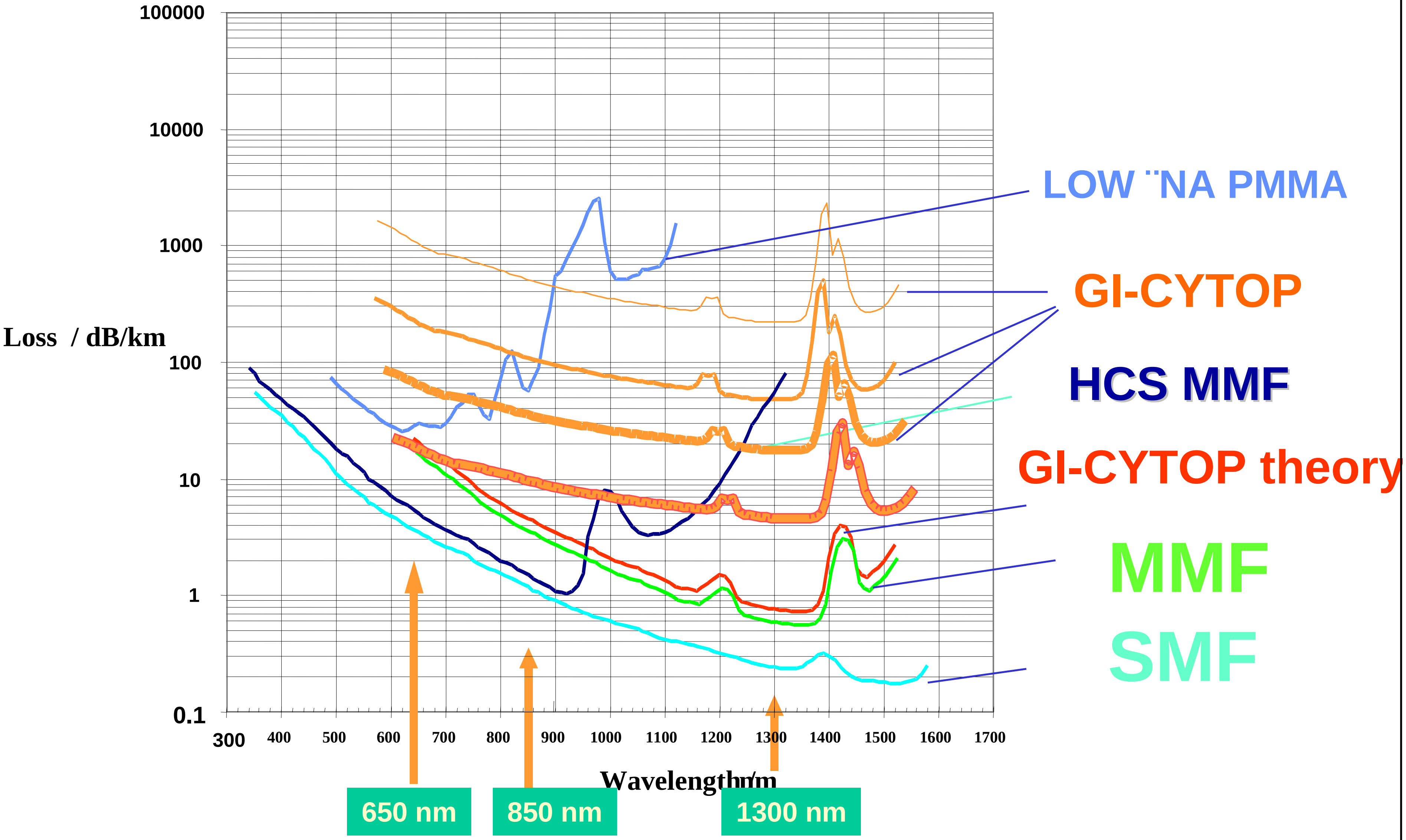
Materials intrinsic attenuation simulation



Simulation vs. experiment



POF vs GOF on attenuation



POF Applications

Industrial applications

SI PMMA ++

Automotive

SI
PMMA

Aerospace

GI
PMMA

10/100MBps

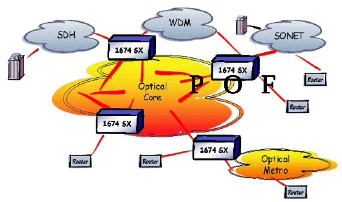
Focus on mechanical properties

Focus on combination of bandwitdh and mechanical properties

> 1 GBps

Interconnection

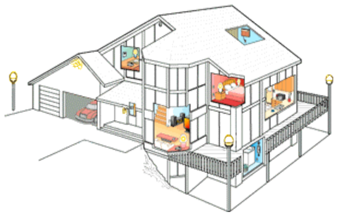
Central office



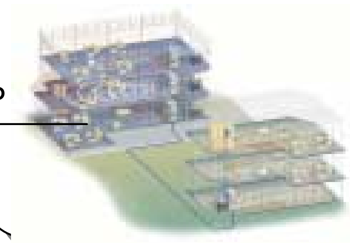
GI CYTOP

GI CYTOP

Fibre to the Home
Home Networking



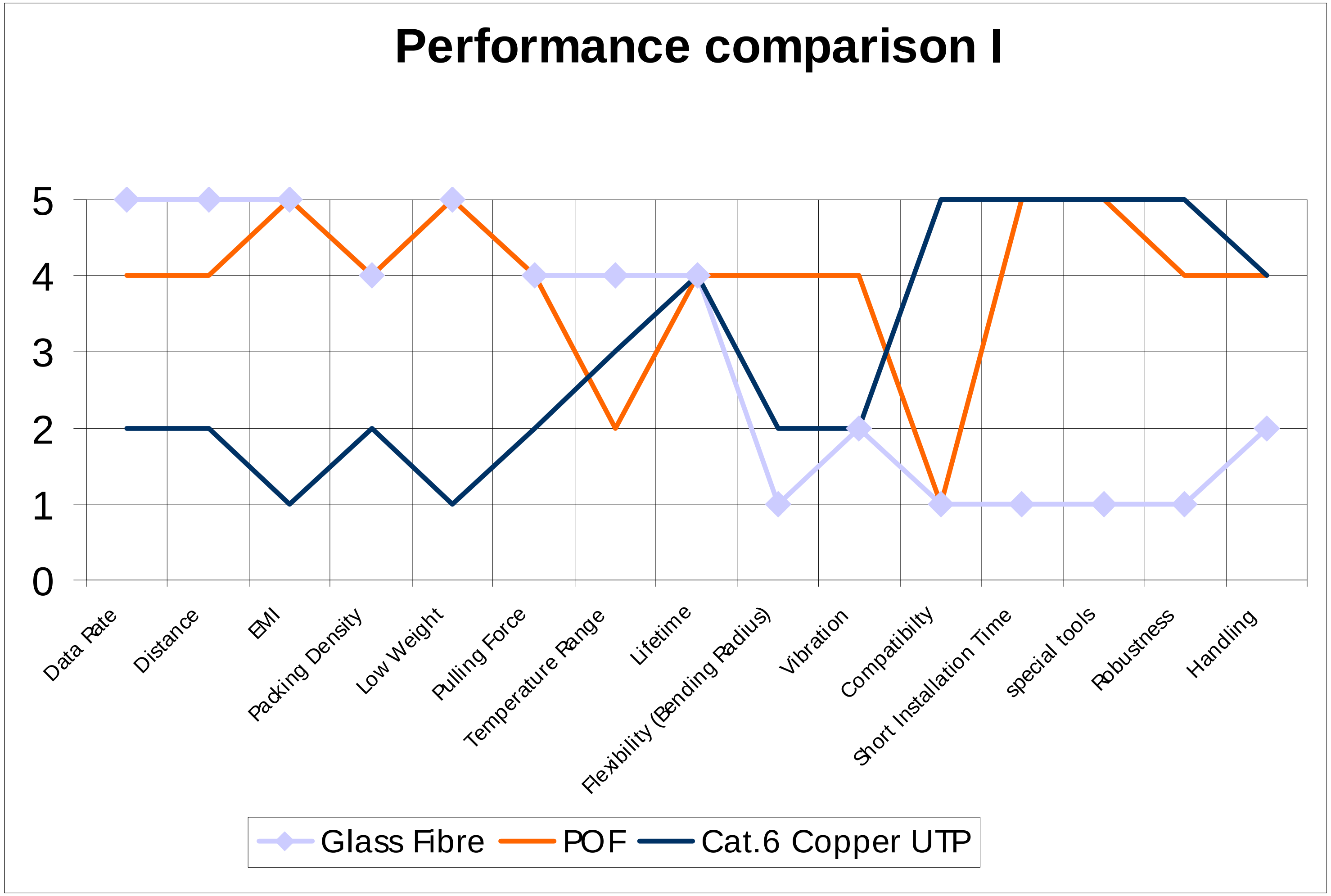
Local Area Network



GI CYTOP

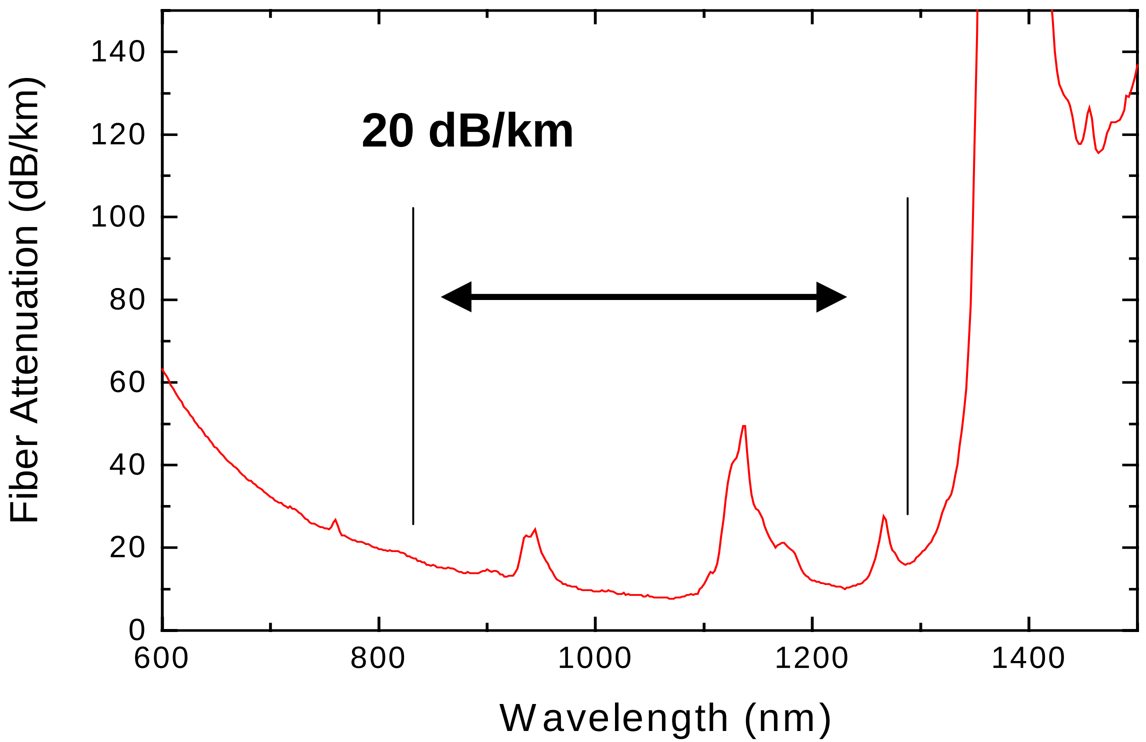
Performance Comparison

- **POF combines benefits of both copper and glass**



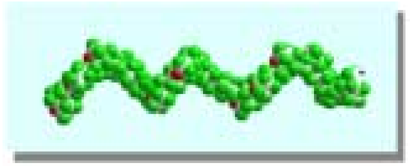
Wavelength Support

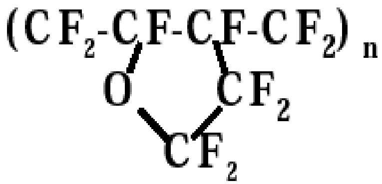
- 3 windows
- Broad range of wavelength supported:
  650nm 850nm 1300nm
- Flat curve allows deviation from center wavelength



Fibre Products

- ✓ **High bandwidth POF types**
  - ✓ Bandwidth above 1 Gbps
  - ✓ CYTOP Polymer only
  - ✓ GI-POF only

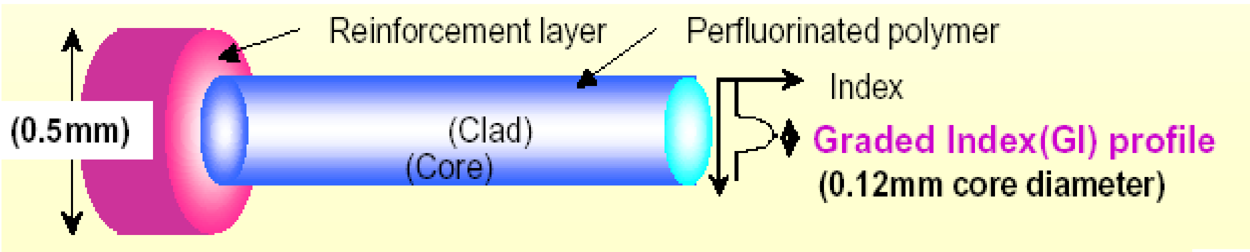


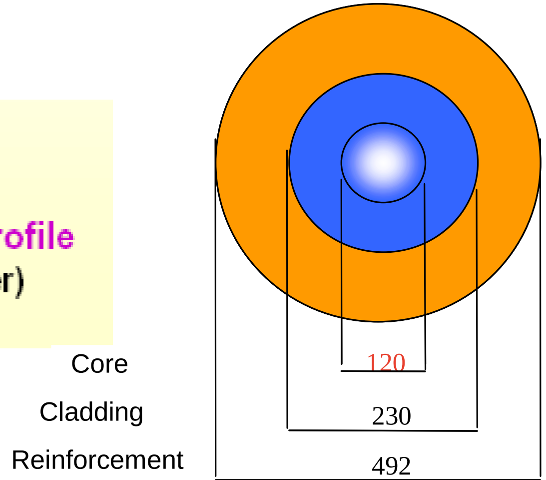


- ✓ **Advantages**
  - ✓ Support for all applications (High Speed and Low Speed)
  - ✓ Support for all wavelength (510,650,850,1300nm)
  - ✓ Support for existing light sources (used for Silica fibre)
  - ✓ Known cable construction from GOF cable

Fibre Products

- **Type 1:**
  - **120µm core,** 500µm outer diameter

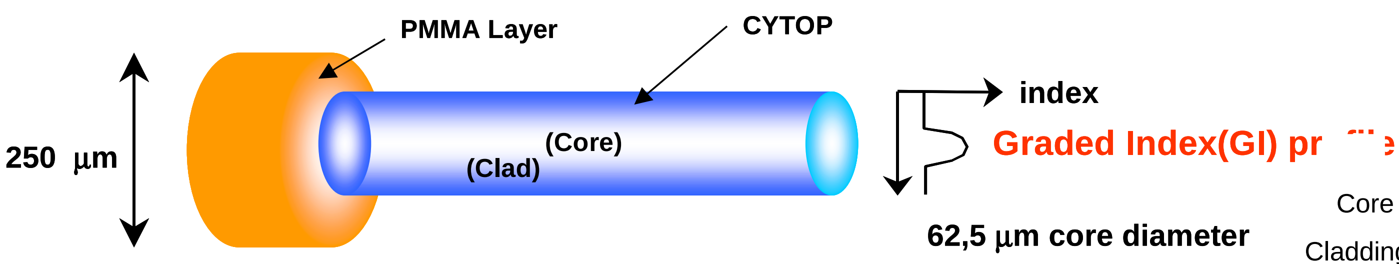


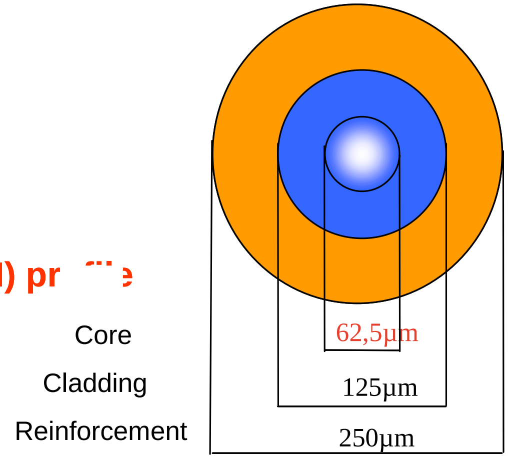


  - Diameter supports ”Ease of Installation” and enables on-site termination
  - High Speed, 1Gbps
  - Applications: **LAN, Industrial, Telecom, (near-term)**

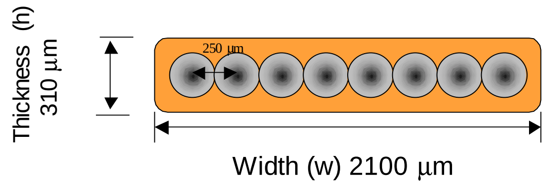
Fibre Products

- **Type 2:**
  - **62,5 µm core,** 250µm outer diameter





  - Diameter allows higher bandwidth and ribbon cable structure
  - Ultra High Speed, 10Gbps
  - Applications: **Interconnect, LAN, (long-term)**



Fibre standards

➢Draft specifies 4 new types of perfluorinated GI-POF

	A4e	A4f	A4g	A4h
Principal applications	consumer electronics	industrial, mobile	SOHO LAN	high speed, multi-Gb/s
Outer diameter (µm)	750 ± 20	490 ± 10	490 ± 10	250 ± 5
Core diameter (µm)	500 ± 20	200 ± 10	120 ± 10	62.5 ± 5
Attenuation at 650 nm (dB/km)	≤100 dB/km	≤100 dB/km	≤100 dB/km	n/a
Attenuation at 850/1300 nm (dB/km)	≤40 dB/km	≤40 dB/km	≤40 dB/km	≤40 dB/km
Minimum modal bandwidth at 650 nm (MHz-km)	80	80	80	n/a
Minimum modal bandwidth at 850/1300 nm (MHz-km)	150-300	150-400	150-500	150-500

IEC 60793-2-40
IEC SC86A/WG1

Industrial Cabling Sandard

- Standards
  - POF included in Draft for ISO/IEC 24702 Industrial Cabling
    - New Fibre Classes OF100 and OF200

Table 3 – Channel attenuation of optical fibre cabling channels

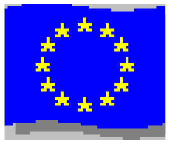
Class	Maximum channel attenuation dB				
	510 nm	660 nm	850 nm	1300 nm	1550
OF-25	ffs	5,5	4,0	4,0	
OF-50	ffs	8,0	5,0	5,0	
OF100	ffs	10,5	7,0	7,0	
OF-200	ffs	23,0	11,0	11,0	

				1310	1550
OF 300	As per ISO 11801 Ed 2				
OF 500					
OF 2000					
OF 5000				4,0	4,0
OF 10000				6,0	6,0

Nexans Activities

- Nexans Activities are concentrated in NRC Lyon (Central Nexans Research Centre, France)

- Nexans participates in three EU Projects



  - ✓ Motifes
  - ✓ Home Planet
  - ✓ Interconnect by Optics

- To develop interoperable GI-POF products, cooperation among participants to develop connectivity and transceiver components for GI POF

NRC Lyon

- Task:
  - Basic R&D (Materials +Properties)
  - Development of Preform Production
  - Research: Comparision of different production technologies

- Status 2004:
  - POF drawing facilities operating; fibres reach target properties
    - Type 1 120/500µm
    - Type 2 62,5/250µm
  - Sample quantities available
  - Work ongoing for process control and optimisation

Achievements

- ✓ Good optical performance
  - ✓ 10 times better attenuation than SI POF
  - ✓ Support of multiple wavelength 650 / 850 / 1300nm
  - ✓ Good Index profile; Independence of launching conditions
  - ✓ High bandwidth (equal to GOF 62,5/125)
  - ✓ Less modal noise than GOF (better quality for video signal)
  - ✓ Works with available equipment, 850µm cards

- ✓ Good mechanical properties of plastic material
  - ✓ Good ageing and thermal resistance for in-door applications
  - ✓ Low bending radius
  - ✓ Ease of installation

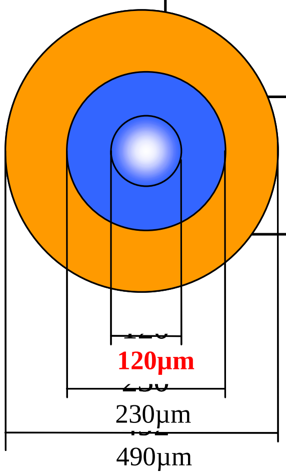
Challenges

- Technical Challenges:
  - Finish distance testing for Gigabit Ethernet
  - Develop connectors that make use of plastic material
  - Develop low cost production processes for base material
  - Develop low cost transceivers that make use of simplified alignment

Nexans

GI POF compared to Gigabit Ethernet Standard

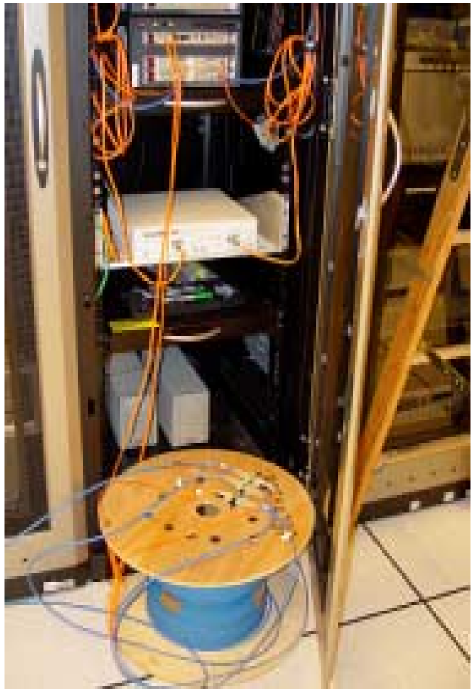
Standard	Fibre	Bandwidth (MHz/km)	Range (m)
1000BASE–SX (850 nm) OM1	MMF 62.5 / 125 MMF 50 / 125 *GI POF**	160 400 *510/812**	220 500 *300*
1000BASE–SX (850 nm) OM2	MMF 62.5 / 125 MMF 50 / 125 *GI POF**	200 500 *510/812**	275 550 *300*
1000BASE–LX (1300 nm)	MMF 62.5 / 125 MMF 50 / 125	500 400 - 500	550 550
1000BASE–LX (1300 nm)	SMF 9 /125	N/A	5000

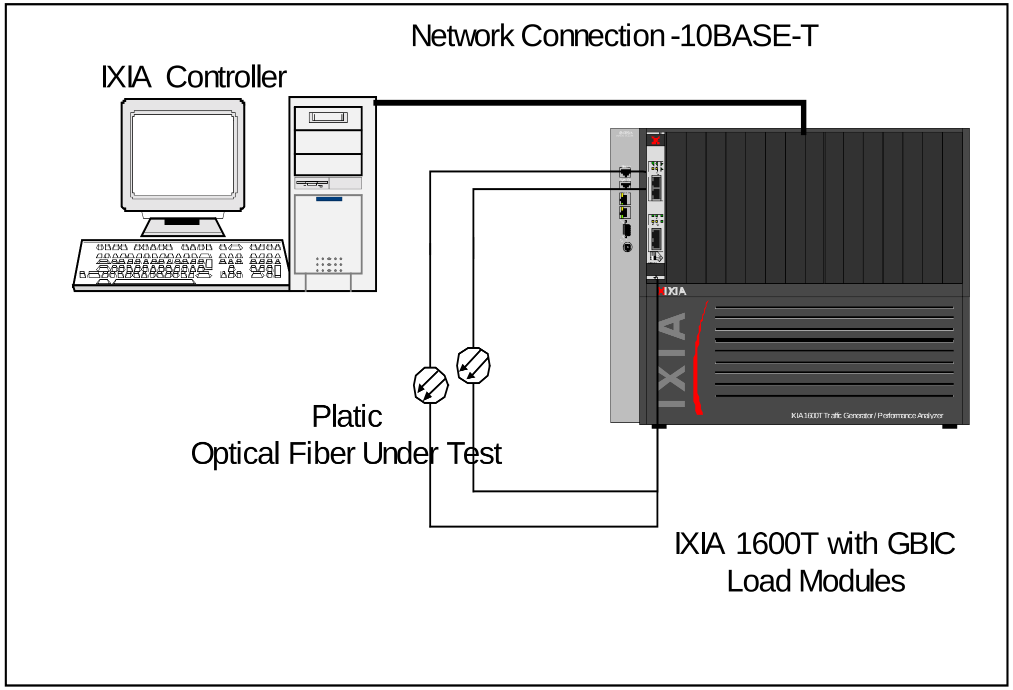


*Due to non linear behaviour the real bandwidth of GI-POF over 1 km would be 812MHz (in case attenuation will lower in future)

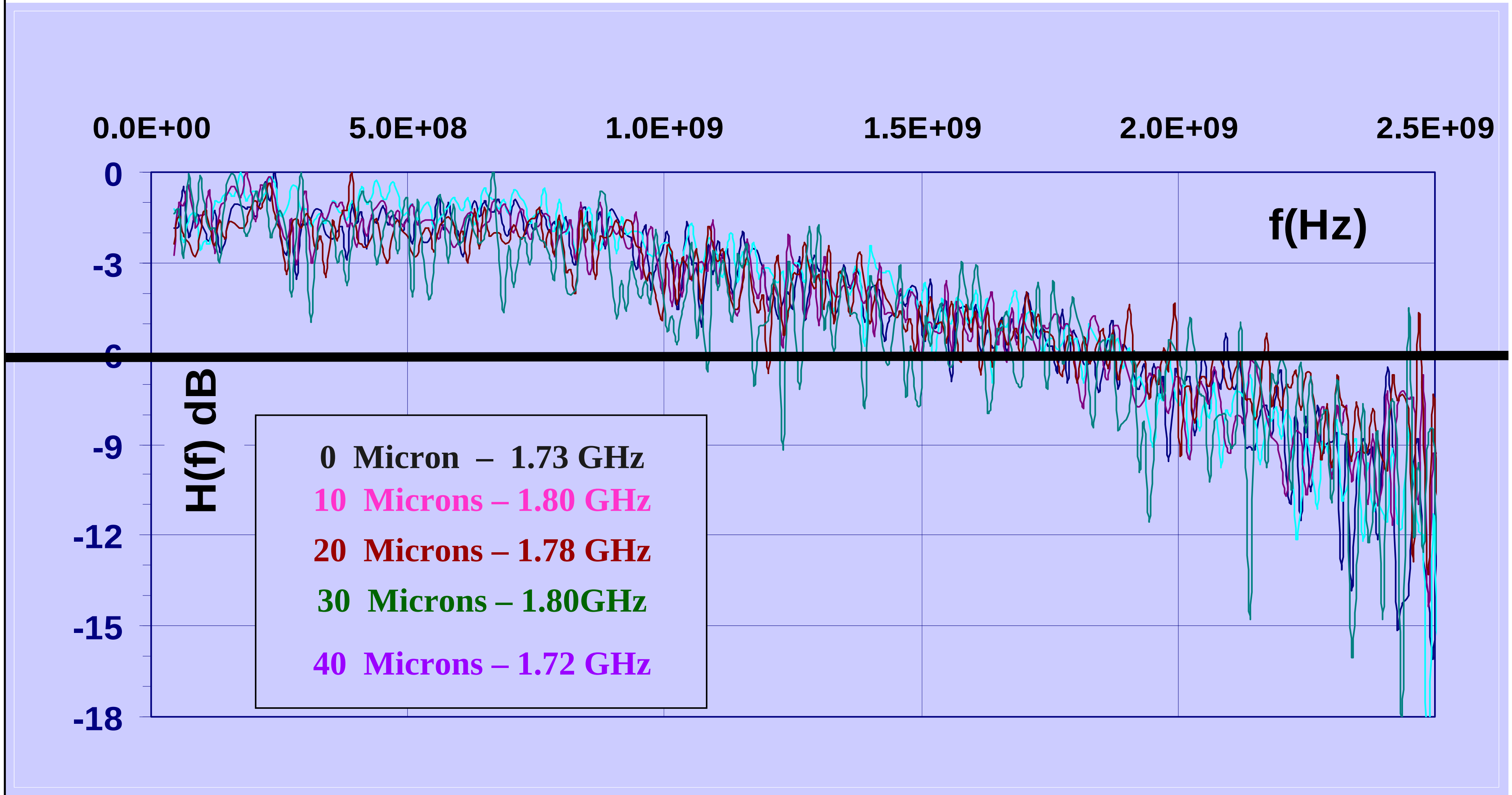
POF Gigabit Ethernet Testing

- Test Setup and Results
  - 400 meters of POF
  - IXIA 1600T Chassis containing LM1000GBIC load modules with 1000BASE-SX GBICs
  - Transmitted over three-trillion 64-byte Gigabit Ethernet packets with 96 ns inner-packet gap with no errors. Translates to a FER of 3.30×10^{-13}.





Bandwidth Performance

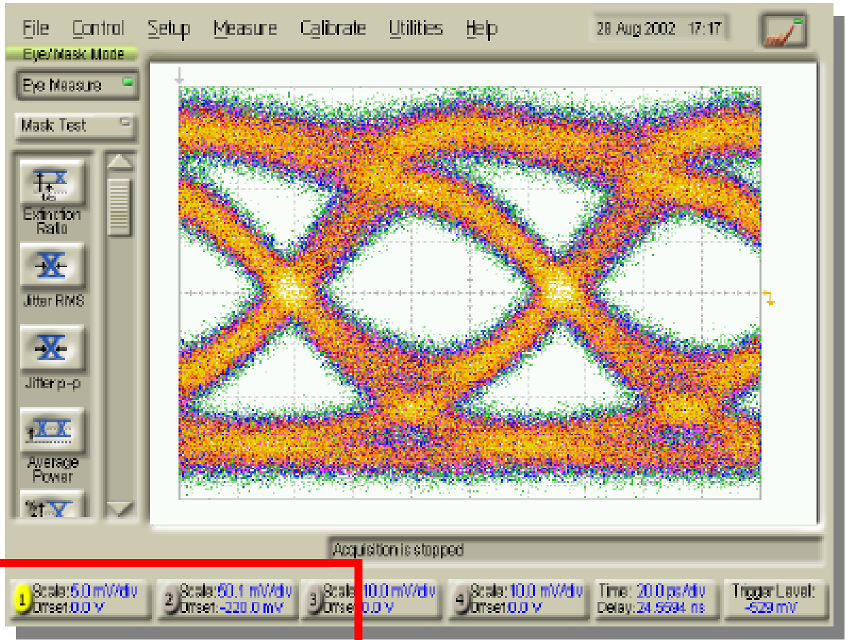


* measured bandwidth on 300m of Nexans GIPOF 120/490 under different launching conditions / offsets

Measurement Results

10.7 Gbit/s Transmission over GIPOF at 850 nm VCSEL (Supplier A)

> 100 m GIPOF; RX: PIN + TIA; optimised offset launch



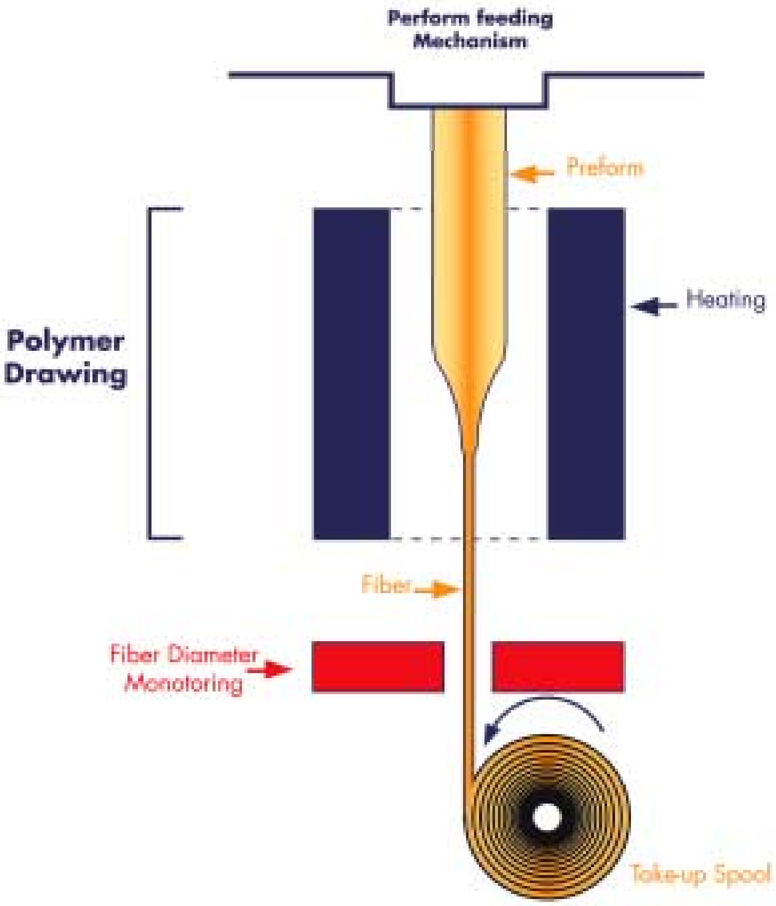
> BER< 10^{-10} achieved

Successful test: 10 Gbps over 100m
Fibre used: 120/230 /490µm GIPOF

Optical fibre production

- Historical methods
- Current techniques
- Future development

Drawing from a preform



Drawing from a preform

- Concentrically manufactured cylinders with different refractive index

Procedure:

- preform is heated until a fiber can be drawn.

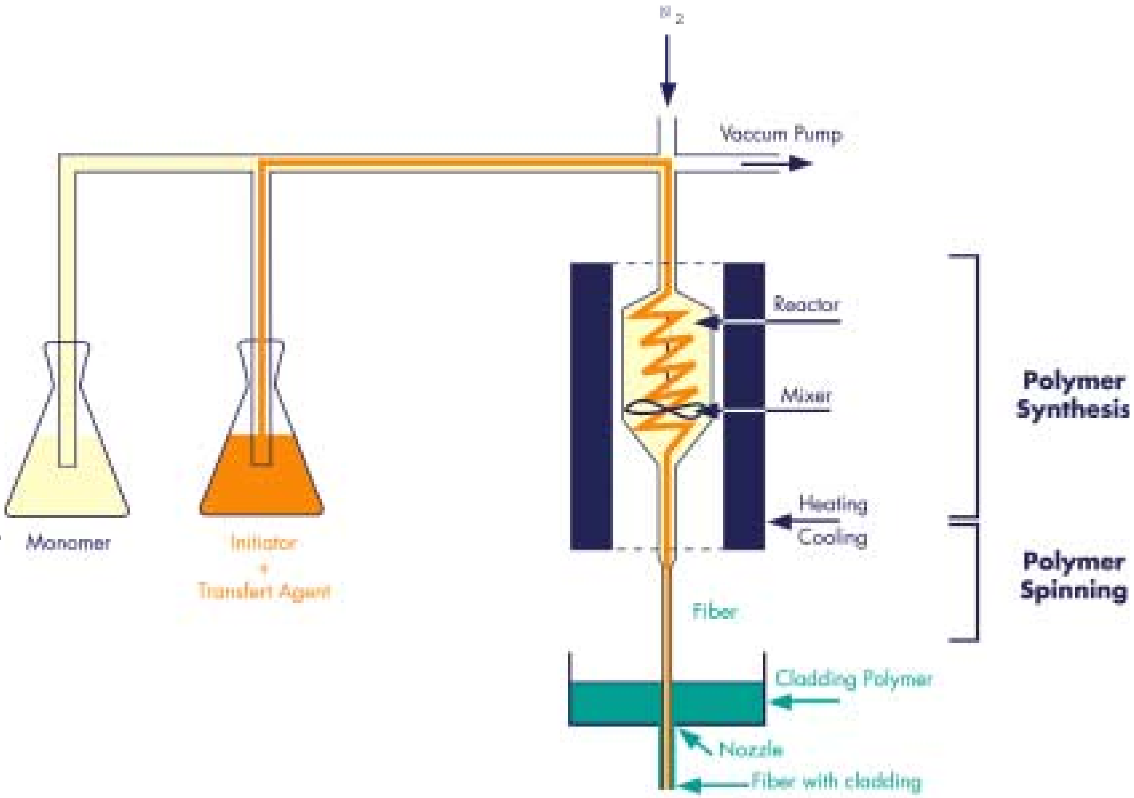
Fiber type:

Step Index POF or Graded Index POF

Comments:

- used for glass fiber manufacturing
- well suited for the production of GI POF

Batch extrusion



D / Batch Extrusion

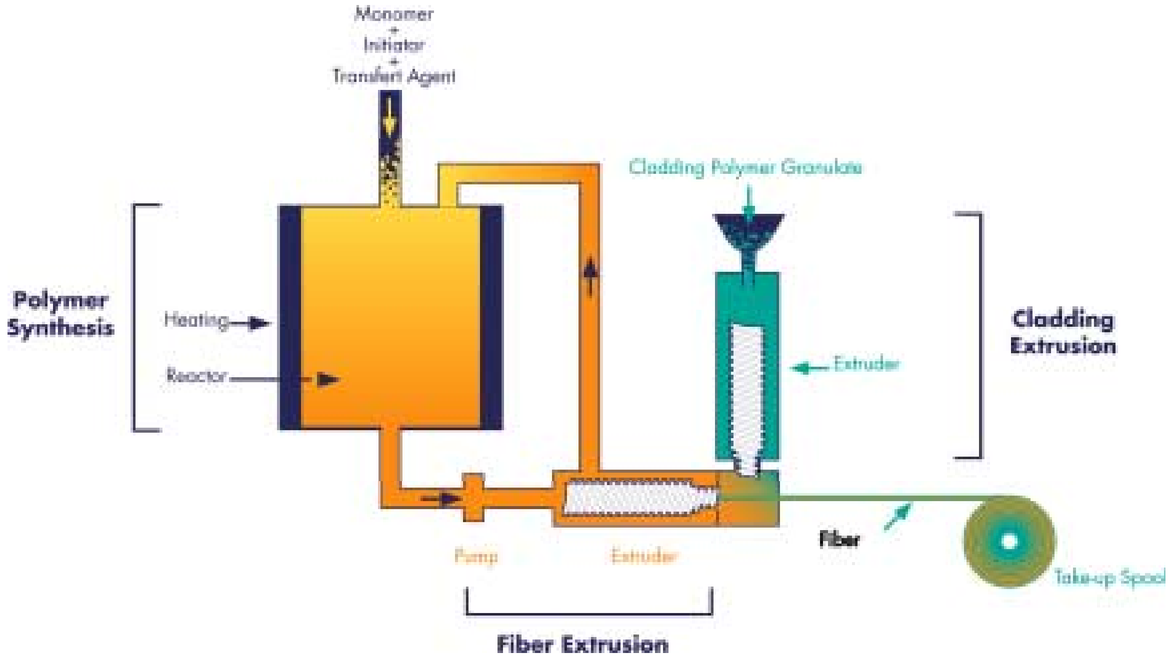
Procedure:

- •monomer distillation
- •addition of initiator and polymerization regulator.
- •the extrusion of through a nozzle with nitrogen
- •cladding immediatly applied.

Fiber type: Step Index POF

Comments: not widely used.

Continuous Extrusion of core and cladding



Procedure:

•pre-polymerized (80%) monomer

•mixture pumped towards the extruder

•second extruder for the cladding

Fiber type: Step Index POF

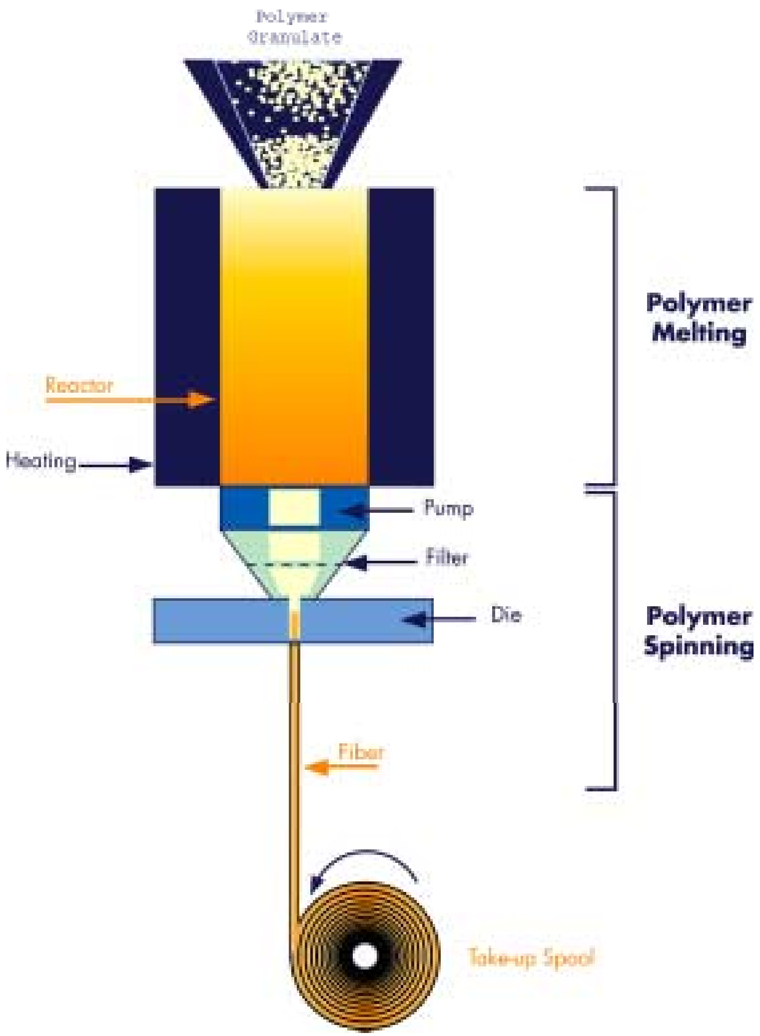
Comments:

•Process suitable for continuously manufacturing POF on a large scale

•very low contamination during the process.

• standard process for SI-PMMA manufacturing.

Melt spinning process



Procedure:

- polymer melted and pressed through a die.
- Cladding applied after fiber formation.

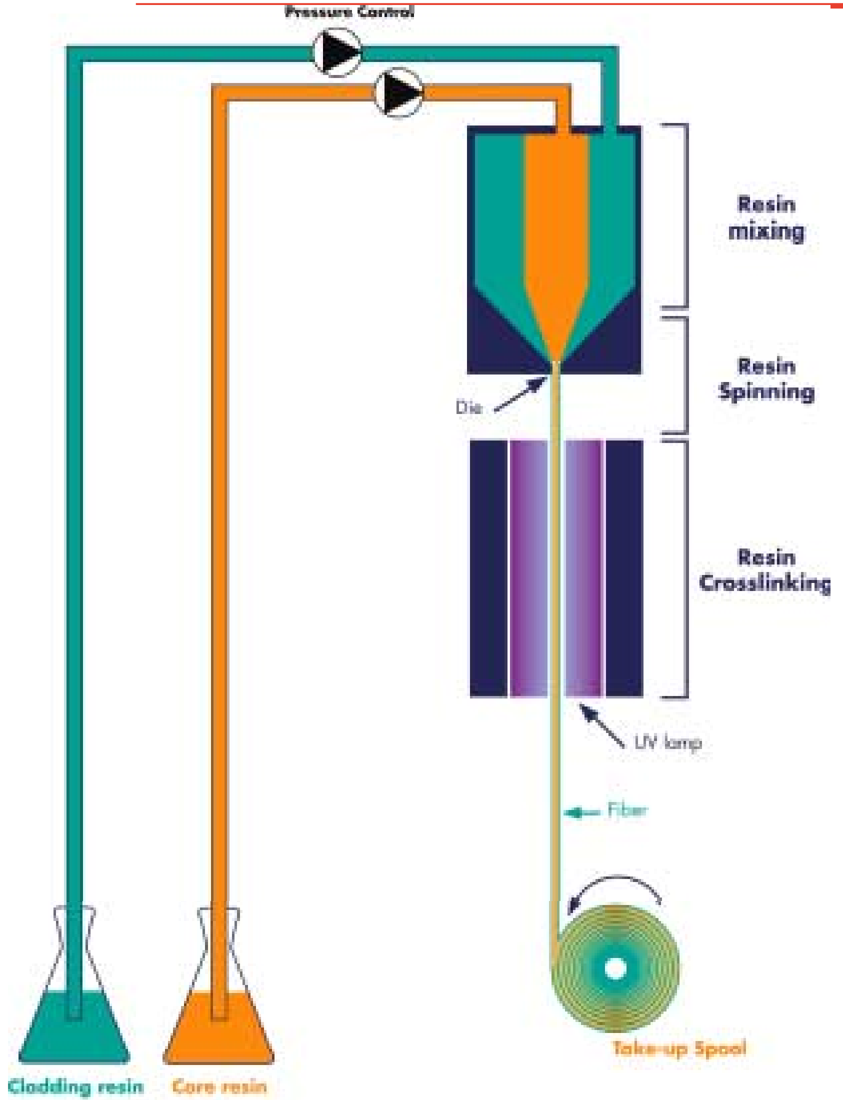
Fiber type:

Step Index POF or Graded Index POF

Comments:

- Possibility to manufacture several fibers simultaneously
- Extremely high drawing speed.
- Technique very expensive to set up.

Direct UV cross-linking of resins



Procedure:

- Cladding and core resins pumped towards a reactor
- Liquid resins flowing trough a nozzle
- UV curing in line.

Fiber type:

Step Index POF or Graded Index POF

Comments:

- Continuous process

Cable Structures for Gigabit POF

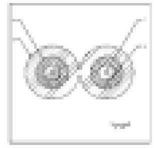
Standards:

- IEC 60794-2-42
  (in preparation)

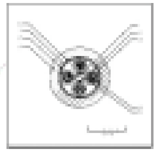
BENEFITS

- Long Lifetime
- No additional buffer to strip
- Enables fast termination
- Drives down total
  networking cost

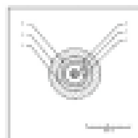
- **SC/ZC Design for Fibre Patch cords**
  - 1/2 fibres 490µm
  - Bending radius* =20mm



- **MC Design for Breakout cabling**
  - 2-4 fibres
  - Aramid strength member

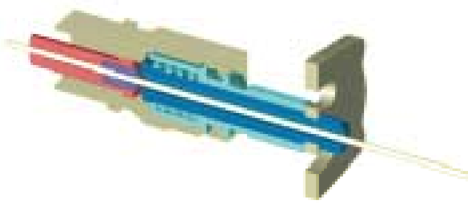


- **UT Design for Backbone cabling**
  - Up to 12/24 Coloured fibres
    490µm
  - Dry tube solutiono



“Easy to install“ Connector for Gigabit POF

- **FERRULE:**
  - New ferrule adapted for Gigabit-POF
  - Supports 2 fibre types: 120/490 and 62,5/245µm
  - Mechanical fixation of the fibre (patent pending)
  - Reusable (no crimp)

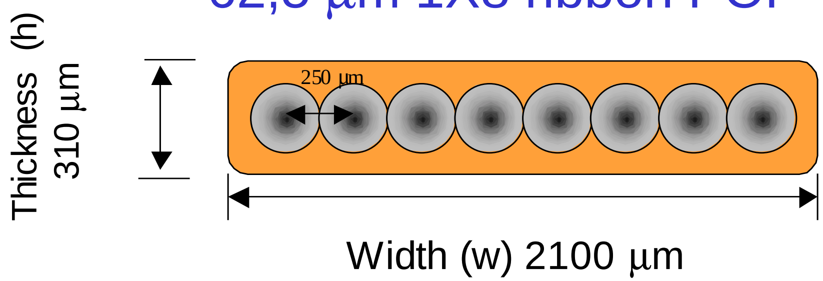


- **CONNECTORS**
  - Usable for SC, ST, LC, MTRJ connectors
  - Compatible to standard components
  - Preassembled connector
  - Avoids glue and heat
  - Polishing not mandatory

- **BENEFITS:**
  - Short installation time
  - Simple termination like copper

Parallel Optics Ribbon GIPOF

62,5 µm 1X8 ribbon POF



Ribbon BW : 8 x 5 GHz @ 100 m

- **40 GHz over 100 m @ 850 nm**

Ribbon Bitrate : 8 x 10 Gbps @ 100 m

- **80 Gbps over 100 m @ 850 nm**

Nexans

European POF Activities

IO (Interconnect by Optics within Electronics Systems)

Objective : Develop high-density high-speed interconnect systems

Nexans	plastic fibre, cable
Alcatel	high-level IP router design
IMEC	modeling, integration,demonstration
FCI	connectivity
RCI	microwiring fibre deposition
PPC	sandwiched diffused glass waveguide

Home Planet

Objective : Build a Home Plastic Optical Fibre Network

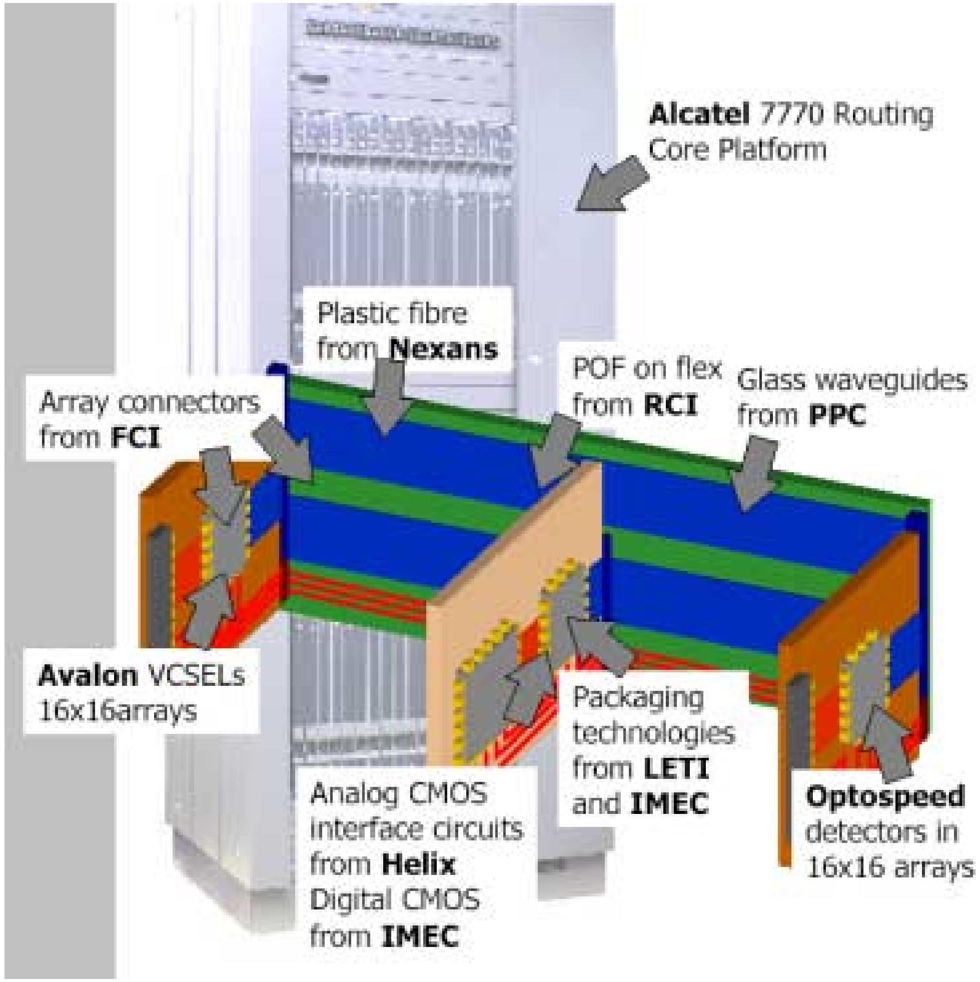
Nexans	plastic fibre, cable, connectivity
NMRC	O/E research, modeling
FireComms	O/E RCLED, VCSEL, Transceivers
Grundig	AV demonstration,1394 & HaVi stacks

MOTIFES

Objective : Elaborate Multimedia POF Technologies for In-Flight Entertainment

University of Surrey	650 nm VCSEL design
NMRC	650 nm VCSEL fabrication
Nexans	High temperature POF
Thales	transceiver development
FireComms	1394-to-PCI board assembly

IO : interconnect by optic



www.intec.rug.ac.be/IO

IO (interconnects by Optics) is a European project, co-funded by the EC, in the framework of the **Information Society Technology (IST)** program
Contract number is IST-2000-28358

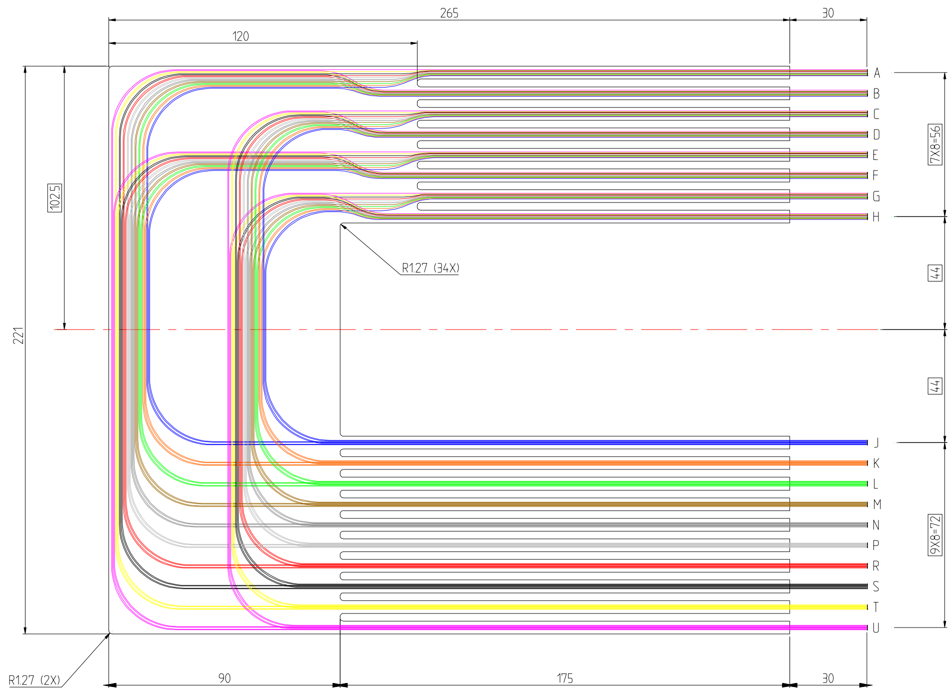
Parallel optical interconnections

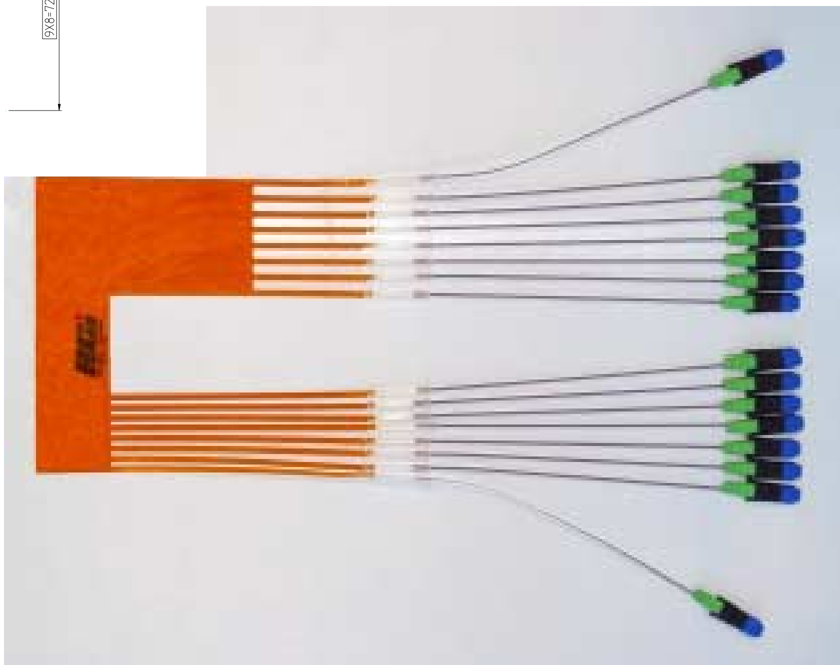
The project runs from September 1, 2001, to August 31, 2004

IO : Interconnect by **O**ptics within Electronics Systems

- Assess trade-offs between parallel and serial I/O modes
- Develop high-density high-speed interconnect systems
  - ✓ between Integrated Circuits (on-board and in-board
  - ✓ between Printed Circuit Boards and Backplanes (on-Backplane and in-Backplane)
- Based on
  - ✓ 2D (up to 256) plastic fiber arrays (stacked ribbons of high temperature small diameter POF fibers,
  - ✓ glass sheet waveguides, operating at 1,25 Gbps/channel
- Consortium: Nexans (plastic fiber, cable), Alcatel Bell (high-level IP router design), IMEC- R.U.Gent (modeling,integration, demonstration), FCI (connectivity), RCI (microwiring fiber deposition). PPC (sandwiched diffused glass waveguide), Caswell, Opto Speed, Helix

GIPOF Flexfoil





Wiring of POF
on flex foils:

Home  Planet

- Elaborate end-to-end European technological capability in the Japan-dominated arena of consumer electronics
- Build a Home Network based on the
  - ✓IEEE1394 interface standard (i-Link, Firewire)
  - ✓HaVi stack (supporting Digital Video broadcasting std)
  - ✓PMMA small numerical aperture fiber
  - ✓650 nm RCLEDs and VCSELs
- Testbed to operate at 200 & 400Mbps (50m)
- Demonstrate 800Mbps and 1600Mbps technology feasibility
- Consortium: Nexans (plastic fibre, cable, connectivity)
NMRC (O/E research, modeling)
FireComms (O/E RCLED, VCSEL, Transceivers)
Grundig (AV demonstration,1394 & HaVi stacks)
IQE (wafer growth)

Aerospace MOTIFES

Multimedia Optical-Plastic Technologies for In-Flight Entertainment Systems

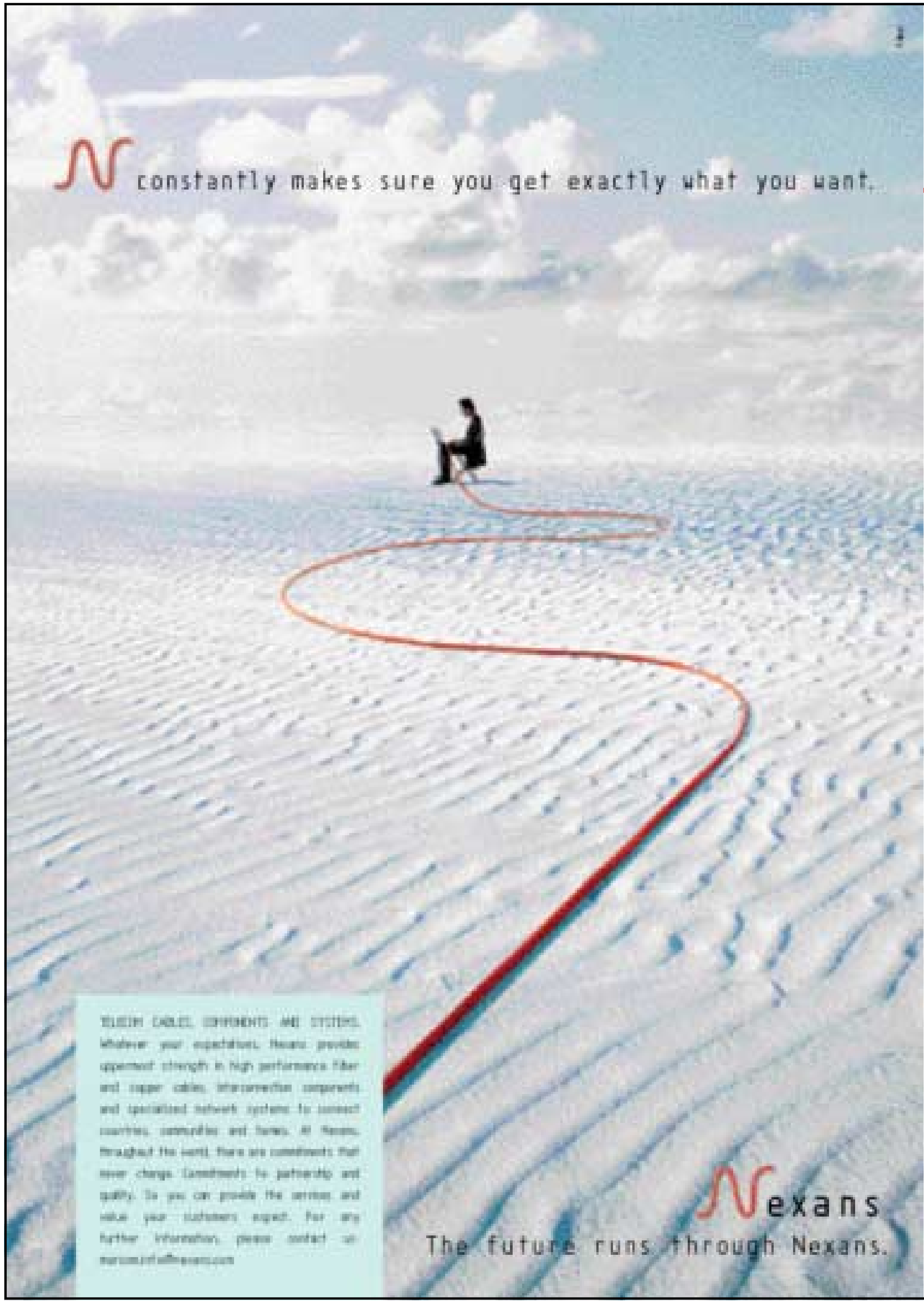
(MOTIFES)

<u>CONSORTIUM OVERVIEW</u>

Participant	Business activity
National Microelectronics Res.Centre (NMRC) Ireland	650 nm VCSEL fabrication/environmental test
Department of Physics, University of Surrey, UK (UNIS)	650 nm VCSEL design/ wafer characterisation
Nexans Filotex, France	GI-POF development/environmental tests
Thomson-CSF/LCR, France	transceiver development/ 850 nm VCSEL fabrication
FireComms Ltd, Ireland	1394-to-PCI board assembly

Conclusions

- POF capacity for improving usefulness of multimode optical fiber has been demonstrated
  - Simplified termination
  - Superior resistance to mechanical stress
  - Improved bandwidth
- Combined advantages of MMOF and Copper
- Practical and relevant POF components development is underway
  - Supports 850nm
  - Supports gigabit networking
  - Wider distance scalability



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