Recent results on characterisation of PF GIPOF designed for high-speed LAN

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The paper highlights some recent results obtained on perfluorinated Graded Index Polymer Optical Fibres (PF GIPOF) of different core diameters. The fibres under test (FUT) are drawn from the preform and from the continuous extrusion processes. The results are given in terms of attenuation, bandwidth, sensitivity to radial offset launch, differential mode delay and bit error rate in a 10 Gbit/s transmission. All the measurements were made at 850 nm which is the common wavelength used in LAN.

***Index Terms*— Perfluorinated Polymer Fibre, transversal offset launch, Differential Mode Delay (DMD)**

INTRODUCTION

Manufacturers of silica fibres have developed Extended Bandwidth Glass Multimode Fibres able to transmit 10 Gbit/s signal over 300 m length. These fibres – optimized at 850 nm – have a high bandwidth-length product (>2GHz.km). Polymer optical fibres (POF) offer an interesting alternative for the LAN market, especially for Small Office/Home Office and "Do It Yourself" applications where higher attenuation is not critical, because of the availability of low cost connector clips.

Perfluorinated Graded-Index (PF GI) POFs Under Test

Typical core diameter of PF GIPOFs is 120 µm. Core fibre diameters of 50 µm, 62.5 µm are now also available on the market. Given their numerical aperture of 0.19, these fibres closely match standard multimode glass fibre. As such, 50 µm and 62.5 µm GI POFs offer easy termination and compatibility with conventional silica fibre transceivers in 850 nm LAN. Table 1 summarizes the product specifications of the FUTs identified as 50 A, 62.5 A, 120 A and 120 B

	Fibre 50 A	Fibre 62.5 A	Fibre 120 A	Fibre 120 B
Numerical Aperture (NA)	0.19	0.19	0.185	0.18
Core/cladding diameter (µm)	50 / 490	62.5 / 490	120 / 490	120 / 500
Attenuation @ 850 nm (dB/km)	< 60	< 60	< 60	< 30
Specified bandwidth @ 850 nm (MHz.km)	> 300	> 300	> 300	> 500

Table 1: Product specifications of the FUTs

The letter A and B refer respectively to fibres manufactured according to the co-extrusion and the preform processes.

Results

1. <u>Attenuation and bandwidth</u>

Samples of about 200 m have been chosen because they are representative of the distance to be spanned in most preinstalled multimode fibre indoor applications [1]. Table 2 gives the length of the FUTs determined by the backscattering technique. Fig 1 shows the corresponding OTDR traces. Contrary to sample 120 B (preform process), diffusion and absorption centres are observed on the FUTs of type A, more specifically on sample 50 A. The non homogeneities result from extrinsic causes inherent to the co-extrusion process and explain the higher attenuation of the fibres of type A (see Table 1, row 3).

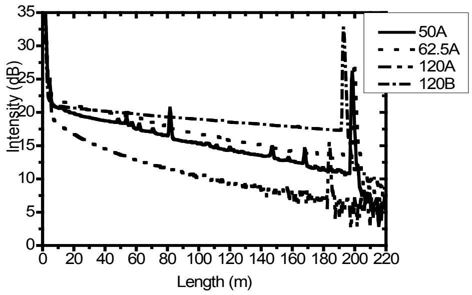

Figure 1: OTDR traces of PF GIPOF samples

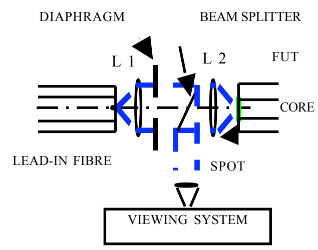

Figure 2: Launching Optics test set-up

Attenuation and bandwidth are measured under underfilled launch conditions (see results table 2). These typical conditions are commonly used when VCSELs operate as light sources for short to medium distance LAN applications. The baseband response is obtained in the time-domain via an optical sampling oscilloscope (OSO) of wide bandwidth (> 20 GHz) and wide effective detector area (2.5 mm x 1.5 mm). The deconvolved impulse response is calculated from the broadening of a narrow input pulse (50ps) at the output of the fibre under test.

FIBRES	OTDR		OSO
	ATT@ 850 (dB/km))	L (m)	BP@ 850 (GHz)
120 B	26.45	198.2	1.4
120 A	58.1	195.6	3.2
62.5 A	51	198.6	2.6
50 A	53.7	197	1.6

Table 2: Lengths, attenuation and bandwidth of the FUT

2. Baseband responses versus radial offsets of a restricted launch spot [2]

The launching optics in Fig 2 is composed of a lead-in fibre, two lenses, two x y z high precision translators, one beam splitter and a viewing system. The measured insertion loss of the launching optics set-up is 5dB. The transversal offset of the launched spot on the core of the FUT is monitored via the beam splitter thanks to a viewing system.

Given the Lagrange-Helmholtz invariant calculus, the diameter of the launched spot and its numerical aperture can be calculated in function of the core diameter of the lead-in fibre, of its NA and of the focus lengths of lenses L_1 and L_2. Various launch conditions, from OFL (Overfilled Launch) to UML (Underfilled Launch) and even RFL (Restricted Filled Launch), can be obtained by appropriate selection of L_1, L_2 and the lead-in fibres (SMF, MMF 50 µm, MMF 62.5 µm,…). Fig 4 illustrates the evolution modal bandwidth in function of the transversal offset when a restricted launch spot stimulates the fibre under test. Contrary to samples of type A, PF GIPOF drawn from a preform [3] is not sensitive to transversal offsets. Near field patterns (NFP) at the output of the FUTs confirm these results (see Fig. 5 and 6).

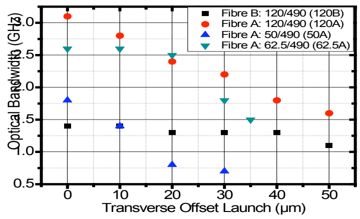

Fig. 4: Bandwidth versus spot offset

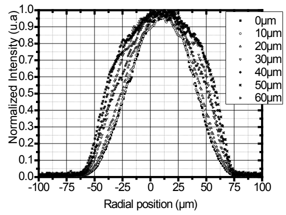

Fig. 5: NFP of 120 A

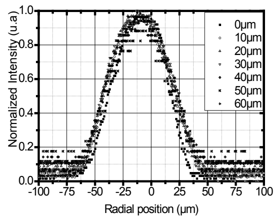

Fig. 6: NFP of 120 B

3. Differential Mode Delays

Depending on the index profile and the wavelength, mode groups propagate at different velocities and the difference in propagation time between the fastest and the slowest mode groups is known as the Differential Mode Delays. Table 3 gives the DMD for the four samples. Using the test setup described above, the normalized DMD is calculated according to formula (1) :

$$DMD = \frac{\left| T_{slow} - T_{fast} \right| - \Delta T_{Short\_length}}{length} \qquad (1)$$

In (1), T_{slow} and T_{fast} represent respectively the transit times of the slowest and the fastest modes measured at 25% of their maximum intensity, Δ_{Tshort_length} is the pulse width at 25% measured at the output of the fibre under test of 1 m.

FUT	120A	120B	62.5A	50A
DMD (ps/m)	2.7	3.97	3.15	3.68

Table 3 –Differential Mode Delay of the FUTs

Fig 7 illustrates the transit time of various mode groups excited in fibre 120 B

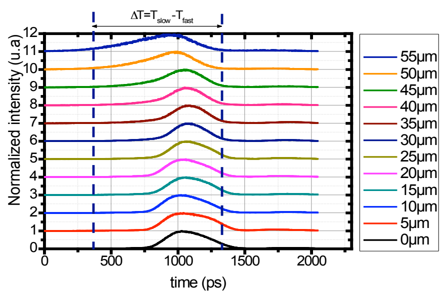

Fig. 7 – Impulse response versus radial offset launch

As well known [4], DMD can degrade the modal bandwidth of the fibre. DMD indicates also how bandwidth changes with the launching conditions. Results in Table 3 confirm the results of Figure 4 for zero offset.

4. Bit Error Rate (BER) results at 10 Gbit/s

The performance of the transmission (samples 50 A and 120 B) is analysed in terms of BER (Bit Error Rate) and power penalty. The evaluation has been conducted with cost-effective, fully duplex 850 nm O/E transceiver which complies high-speed 10 Gb/s optical signals. The electrical interface transceiver is fully compliant with the 10 Gigabit Small Form Factor. The transceiver is composed of a Vertical Cavity Surface Emitting Laser (VCSEL) and of a PIN photodiode. LC connectors provide the optical interface with the fibre under test. The specified average optical power of the VCSEL is -2.5 dBm and the stressed Rx sensitivity is -7.5 dBm. Two fibre samples have been selected: 120 B (83 m) and 50 A (103 m). BER of 2.62 E-14 have been measured for sample 50 A (16 hours) and 5.4 E-14 (23 hours) for sample 120 B. Fig 8 shows the BER test set-up to characterize the dispersion penalty and Figure 9 illustrates the evolution of the BER when the received average power at the input of the PIN receiver is changed. The back-to-back curve is measured at the output of 1 m of the FUT. The power penalties due to the modal dispersion and noise are respectively 2.3 dB and 3.7 dB for the samples 50 A and 120 B.

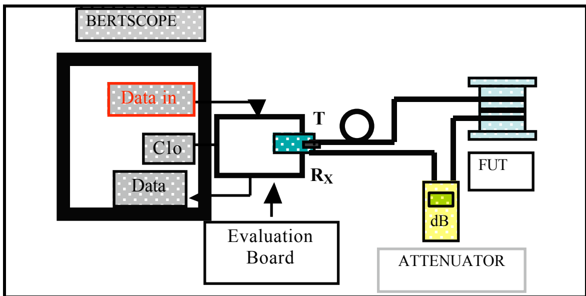

Fig. 8: BER Test set-up

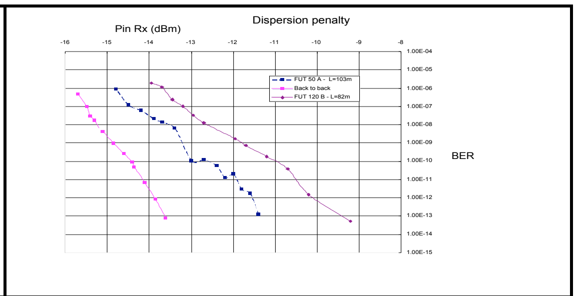

Fig. 9: BER versus Rx input power

Conclusions

Modal behaviour of PF GIPOFs of different core diameters and from two different manufacturing processes have been assessed. Fibres drawn according to the co-extrusion technique have a higher bandwidth but also a higher attenuation. Sensitivity of the modal bandwidth to transversal offset in RML conditions has been observed and this observation has been validated by NFP analysis. DMD measurements have confirmed the bandwidth measurements when the FUTs are stimulated in RML conditions. The bandwidth-length product of the PF GIPOFs is less than the 2GHz.km of the new extended bandwidth Glass MMF but is perfectly adequate for 10 Gb/s Small Office LAN typical applications (less than 100 m) while the insensitivity to the operating wavelength opens the road to wavelength multiplexing transmissions.

References

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