Development of Infrared Optical Links Using Perfluorinated Polymeric Optical Fibres

Sebastião S. O. Júnior, Ricardo M. Ribeiro, Andrés P. L. Barbero and Odair S. Xavier

***Abstract*— This paper reports preliminary researches of optical links based on perfluorinated (PF) polymeric optical fibres (POFs) using infrared light carrier and related components. An infrared datacom-type LED emitting at ~ 945 nm is characterized. Lensless LED-POF and POF-photodetector optical coupling was developed enabling the use of 20 m length of CYTOP^{TM} PF-POF. Applications as ~1 km optical links and low-noise analogue transmissions of low-frequency radio signals (Wireless-over-Fibre – WoF) are firstly envisaged.**

Keywords—Optical Fibres, Perfluorinated Polymers, Optical Communications, Light-Emitting Diodes, Optoelectronics.

***Resumo*—Este artigo descreve pesquisas preliminares sobre enlaces ópticos utilizando fibras ópticas poliméricas (POFs) fluoretadas (PF) utilizando portadoras ópticas no infravermelho e dispositivos correlatos. LEDs infravermelhos do tipo de comunicação de dados emitindo em torno de 945 nm são caracterizados. Foram também desenvolvidos esquemas de acoplamento óptico LED-POF e POF-fotodetetor sem a utilização de lentes, habilitando ao estabelecimento de um enlace de 20m usando PF-POF baseada no polímero CYTOP^{TM}. Primeiramente, pretende-se desenvolver enlaces de ~1 km e realizar transmissões analógicas de baixo ruído de sinais de rádio (Wireless-over-Fibre – WoF) de baixas freqüências.**

Palavras-Chave—Fibras Ópticas, Polímeros Fluoretados, Comunicações Ópticas, Diodos Emissores de Luz, Optoeletrônica.

I. INTRODUCTION

Poly-Methyl-Methacrylate (PMMA) POFs since a long time ago have been used to build short links using visible light carrier [1]. However, PMMA fibres enables limited link typically reaching up 500 m [1]. Graded-index (GI) PF-POFs were first developed in the 1990's and are relatively less known than PMMA POFs. PF-POFs are well suited for optical transmissions in the 850-1300 nm infrared band spectrum presenting < 40 dB/km attenuation coefficient and high bandwidth [1].

In general, short optical links can be highly simplified if it could be deployed using POF technology. The latter is also recognized as much cheaper than silica fibre technology. Further simplifications may be achieved using LEDs instead of laser diodes (LDs) or electro-optical modulators, depending on the required bandwidth.

This paper reports some preliminary experimental researches on PF-POFs and related components to be applied on the development of transceivers and short-haul infrared links aiming to reach ~ 1 km or more and starting at low-frequencies (< 120 MHz).

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II. CHARACTERIZATION OF IR-LEDS

Four basic electrical/optical characterization measurements of the IFE91A model datacom-type IR-LED from Industrial Fiber Optics (USA) were carried out.

Figure 1a shows the IxV plot. A threshold voltage of V_{thr} = 1.10 V is achieved. Figure 1b shows the PxI plot. A reasonable linear response is observed in the range 0-50 mA enabling such LED for analogue transmissions.

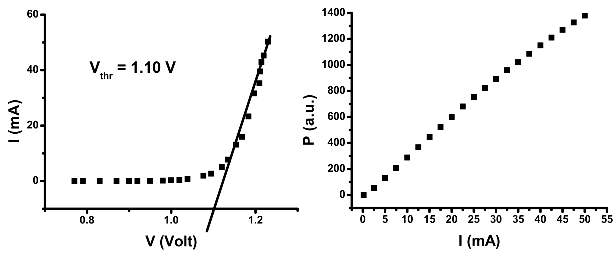

Fig. 1. (a) IxV and (b) PxI responses of the IFE91A model IR-LED.

Figure 2a shows the plot of the IR-LED optical spectrum emission acquired by using the multimode input of an Optical Spectrum Analyzer (OSA). The central wavelength is achieved as ~ 945 nm almost independent of the drive current and ~ 46 nm spectral width. Figure 2b shows the plot of the frequency response of the IR-LED leading to ~ 450 kHz (-3 dB) bandwidth that it is in reasonable agreement with the 1 μs rise time (τ_R) and fall time (τ_F) as disclosed by the manufacturer.

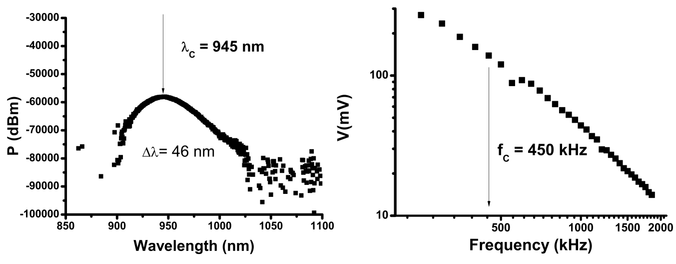

Fig. 2. (a) Optical spectrum and (b) frequency response of the IFE91A model IR-LED.

III. OTHERS DEVICES AND PERFLUORINATED POF LINKS

Figure 3 shows a picture of the optical receiver module optically coupled to the 20 m length of GigaPOF-120LD model PF-POF from Chromis Fiber (USA), graded-index, 120/750 μm core/fibre diameter, 0.185 numerical aperture and < 50 dB/km attenuation coefficient (780-1310 nm).

The receiver module comprises the 40 kΩ transimpedance gain 125 MHz bandwidth (amplified) 1801-FS Si model photo-receiver from New Focus (USA). As shown in Figure 3, a custom and simple lensless optical coupler to connect the receiver with the PF-POF was designed and built. Similar lensless optical coupler was also used to launch the light from the IR-LED into de PF-POF. Another higher gain amplified photo-receiver 2053-FC model also from New Focus (USA) will also be used. Both photo-receivers are ready to be connected to an oscilloscope or electrical spectrum analyser.

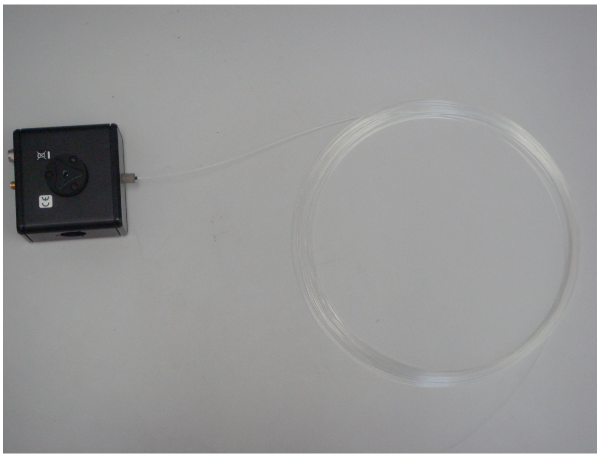

Fig. 3. Picture of the 1801-FS model optical receiver module optically coupled to 20 m length of PF-POF.

The IFE91D model IR-LED with $\tau_R = \tau_F = 3$ ns (~ 120 MHz bandwidth) is able to launch 300 μW optical power into 1mm-diameter POF, instead of the 70 μW delivered by the present IFE91A model. The SE2460-003 model mini-LED from Honeywell (see picture of Figure 4) with integrated 1.45 mm diameter microlens emits 935 nm wavelength, has $\tau_R = \tau_F = 0.7$ μs, 18^o emission angle and deliver 1 mW@50 mA optical power. HFBR series of IR-LEDs from Avago Technologies are also in consideration. All these IR-LEDs will be tested. The main problem remains to perform an efficient optical coupling of the light generated by the IR-LEDs into the 120 μm core diameter of the PF-POF.

Fig. 4. Picture of the SE2460-003 mini-IR-LED model from Honeywell.

Because of noncoherent nature of the light emitted from LEDs, lower intensity fluctuations when compared with LDs or electro-optical modulators [2] is expected, thus enabling larger signal-noise-ratio in analogue links. Although in general commercial LEDs have slow response when compared with LDs or electro-optical modulators, recent researches have shown multi-GHz modulated light-emitting transistor and diodes [3] that are promising milestones.

In order to simplify the manufacturing, manipulation, to provide robustness and lowering the cost of low-frequency (starting at < 120 MHz) Wireless-over-Fibre (WoF) systems, since 2006 our group have been carried out probably the unique efforts on systematic development of simple systems named as "optoelectronic probes" [4]. Optoelectronic probes are useful for measurement/tracking of radio signals [4] or can be adapted to be a complete WoF links. Using PF-POFs the WoF links may be simplified to reach up to few kilometres distances. When the required bandwidth is in the MHz domain, the WoF links may be further simplified by using LEDs. Therefore, the signals may be remotely photo-detected with an amplified silicon photo-diode and displayed on an oscilloscope or electrical spectrum analyzer.

In conclusion, the next step in our development is to show analogue transmissions from 1 MHz to 120 MHz bandwidths using the optics and optoelectronics components previously described.

REFERENCES

[1] O. Ziemann, J. Krauser, P. E. Zamzow and W. Daum, *POF Handbook: Optical Short Range Transmission Systems.* Springer-Verlag, 2nd edition, 2008.

[2] S. L. Rumyantsev, M. S. Shur, Y. Bilemko, P. V. Kosterin and B. M. Salzberg, "Low frequency noise and long-term stability of noncoherent light sources", *Journal of Applied Physics*, v. 96, n. 2, pp. 966-969, 2004.

[3] G. Walter, C. H. Wu, H. W. Then, M. Feng and N. Holonyak Jr., "Tilted-charge high speed (7 GHz) light emitting diode", *Applied Physics Letters*, v. 94, pp. 231125-231127, 2009.

[4] R. M. Ribeiro, O. Da S. Xavier, J. A. M. Souza and A. P. L. Barbero, "An Optoelectronic Probe With Loss Compensation for Electromagnetic Monitoring at Low Frequencies", *Measurement Science and Technology*, v.20, n. 11, PP. 115111.1-115111.9, 2009.