Micro-Structured Plastic Optical Fibres (mPOFs) Doped With CdSe/Zns Quantum Dots Intended for Optical Amplification

D. S. V. Medeiros[1], R. M. Ribeiro[1], A. P. L. Barbero[1], P. H. D. Ruas[1], L. C. Barbosa[2], E. F. Chillcce[2] and R. E. R. Gonzáles[2]

***Abstract*—This paper reports the manufacture, doping and optical characterization of star-type (Poly-Methyl-Methacrylate) PMMA mPOFs doped with CdSe/ZnS quantum-dots, which are intended to be a visible optical amplifier media for "short-waves" (< 600 nm, specially 570 nm) for PMMA POF links.**

Keywords*—*Quantum Dots, mPOF, Optical Amplifier.

I. Introduction

Visible optical amplifier for PMMA POF links has been investigated in the last years to extend their short reach [1]. The channel centered at 570 nm suffer a minimum attenuation in PMMA POFs [1], i.e. 85 dB/km @ 568 nm [3] or even 69 dB/km @ 566-570 nm [4]. However, LEDs emitting at 570 nm are not enough developed for data communication yet and commercial 570 nm LDs are still unavailable. Nevertheless, because of this low attenuation window, it is of interest and is expected the availably of powerful and fast-modulated optical sources emitting at 570 nm in the near future.

The standard PMMA POF of 1 mm-core diameter and 0.46-0.51 range numerical apertures is still the most fabricated in the world and it is cheap, easy of handle and mechanically resilient [1]. They are commonly used in car networks, automation systems, Datacom, home wiring, Fibre-to-the-Home (FTTH) access networks, sensors and illumination [1].

In this paper, we show experimental results on the manufacture and optical characterization of PMMA star-type mPOFs doped with CdSe/ZnS quantum-dots (QDs), primarily intended to be an optical amplifier media for "short-waves" (<600 nm) of visible spectra through PMMA POF links, especially for 570 nm channel.

II. The Manufacture of the mPOFs

The mPOFs were produced on laboratory environment by means of the well-known extrusion technique from PMMA pellets. The pellets are heated and the melted PMMA is extruded through a suitable designed star-5 or star-6 shaped die [5]. The CdSe/ZnS (core/shell) quantum-dots dispersed in a toluene colloidal solution ED-C11-TOL-0560 (Hops Yellow) are used as an inorganic doping which absorbs at λ_{abs} = 545 nm and emits at λ_{em} = 559 nm. This colloidal solution is pulled into the cavities of each mPOFs by using a syringe. The toluene is an organic solvent that enables the diffusion of the quantum-dots through the mPOF, by etching its internal surface. This process is stopped after less than one minute by pulling compressed air that dries the toluene and remains for about one hour. The mPOFs were produced with 1.50-1.59 mm (star-6) and 1.44-1.50 mm (star-5) diameters. At the present stage of our research, the diffusion penetration depth of QD into the PMMA is unknown. Figure 1 shows a micro-photo of the PMMA QD-doped star-6 mPOF. Instead of "open" star as reported earlier [5], now the mPOF is extruded as a "closed" star.

Fig. 1. Fig. 1. Micro-photo of the PMMA QD-doped star-6 type mPOF.

III. The Optical Characterization Results

Three types of optical characterization measurements all in the visible spectra were carried out on the mPOF samples using a Thorlabs CCD spectrometer model SP1-USB operating in the visible range (400-800 nm): spectral transmission, fluorescence emission and optical amplification trials.

A. *Transmission measurements*

Herein a small broad-spectra lamp was used as a light probe. Figure 2 shows the normalized transmission spectra for 22 mm length of a pure PMMA star-6 mPOF. A 50 nm wide transmission band around 500 nm is observed. From 525 nm to 700 nm the transmission spectra is almost flat with T ~ 0.35 relative to the "blue-band", which can also be observed in the QD doped mPOFs.

The insert of Figure 2 shows the transmittance spectrum of a standard PFU-CD1001 PMMA POF from Toray. Such insert was generated from the available manufacturer attenuation coefficient data [3] taking into account 22 mm fibre length. Because the present mPOFs are not hollow-fibres, i.e. it presents solid core, we expect a transmission spectra quite similar to the standard PMMA POF one. The measured transmittance spectrum of the pure mPOF is probably due to presence of OH ions, impurities in the raw MMA or acquired contamination from the extrusion fabrication process. Figure 3(a) shows the normalized transmission spectra for the star-6 QD0560-doped mPOFs, samples #1 (24 mm length) and #2 (17 mm length). It can be observed that, although the sample #2 is shorter than #1, it presents a deeper attenuation valley at 560 nm that matches with the fluorescent emission from the QD0560 in toluene solution.

[1]Laboratório de Comunicações Ópticas (LaCOp), Departamento de Engenharia de Telecomunicações Universidade Federal Fluminense, 24.210-240, Niterói, RJ - Brasil, dianne_scherly@yahoo.com.br

[2]Instituto de Física (IFGW), Unicamp, 13.083-970, Campinas, SP - Brasil, barbosa@ifi.unicamp.br

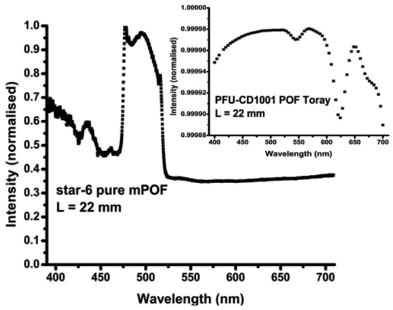

Fig. 2. Fig.2. The transmission spectra of pure star-6 mPOF and standard PMMA POF from Toray (insert).

Figure 3(b) shows the normalized spectra of sample #2 with L = 40 mm and the pure PMMA mPOF (22 mm). As expected, the attenuation valley at 556 nm of sample #2 with L = 40 mm (Figure 3(b)) is deeper than the one for sample #2 with L = 17 mm (Figure 3(a)). The absorption at 556 nm is probably originated from the 545 nm band of the QD0560 toluene solution. Figure 3(b) also shows a narrower and deeper absorption valley at 478 nm (blue).

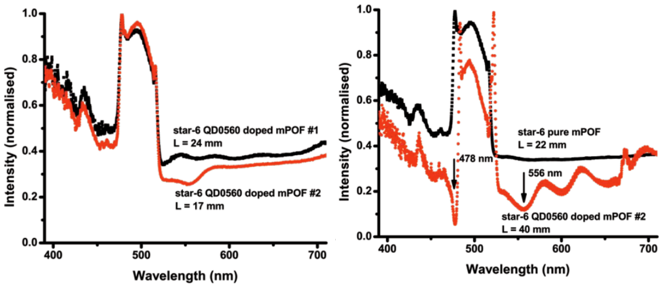

Fig. 3. Fig.3. Transmission spectra of star-6 mPOF (a) samples #1 and #2 doped with QD0560 and (b) #2, compared with pure mPOF.

B. *Fluorescence measurements*

The mPOFs were transversally pumped by two linear arrays of eight (8) ultra-bright blue LEDs for this measurement. Figure 4 shows the emission spectra of sample #2 mPOF with L = 40 mm. It was pumped with 460 nm and an emission peak centered at 565.7 nm and 23 nm wide is observed.

C. *The optical amplification measurement trials*

For these trials, an ultra-bright orange LED nominally emitting at 570 nm model B5B-433-20 572nm@20 mA from Laser Roithner was used as the light signal to be amplified. The probe light was launched into the mPOFs transversally pumped by the blue-LED arrays. Measurements of spectra show that for very low current the LED emits at 572 nm. When the current is increased a small shift of ~ 1 nm in the wavelength peak is observed. Figure 5 shows the orange LED spectrum for 10 mA peaking at 573 nm that remains almost unchanged up to 30 mA. A relatively narrow spectrum of 12.2 nm is also measured.

IV. CONCLUSIONS

The main aim of this work is the development of a PMMA based mPOF optical amplifier doped with QDs. If the amplifier could work with acceptable gain and using practical optical pump sources, it would be suitable for the "orange window" around 570 nm.

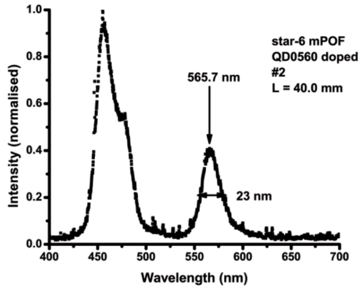

Fig. 4. Fig.4. Emission spectrum from L = 40 mm QD0560-doped mPOF.

With the pump power used up to now it was not possible to observe optical amplification. Furthermore, the 565.7 nm peak of mPOF fluorescence does not match with the 573 nm peak of the orange LED. The wavelength peak λ_{em} of the fluorescence emission depends only on the average size of the QD that can be precisely controlled through chemical [6,7], so it can be slightly increased to match the wavelength of LED emission.

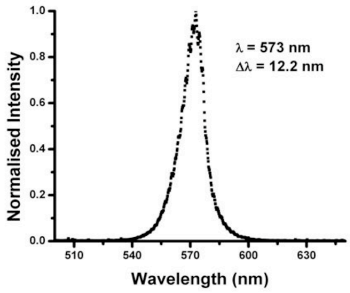

Fig. 5. Fig. 5. The spectrum of the orange LED (to be amplified) at 10 mA current.

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REFERENCES

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

[2] M. G. Kuzyk, *Polymer Fiber Optics: Materials, Physics and Applications*, chapter 6, Taylor & Francis, 2007.

[3] Technical Bulletin, *TBCDG0914PC33-01, Attenuation, PFU-CD1001-22-E and PMU-CD1001-22-E*, July, 14, Toray Industries, 2009.

[4] A. Weinert, *Plastic Optical Fibers: Principles, Components and Installation*, p. 40, Siemens, 1999.

[5] E. F. Chillcce, W. M. Faustino, G. J. Jacob, E. Rodriguez, C. L. Cesar and L. C. Barbosa, "Europium doped optical fibers used as radiation sensors", *SPIE Newsroom*, 20 May, 2007.

[6] Evident Technologies (www.evidenttech.com).

[7] H. C. Y. Yu, A. Argyros, S. G. Leon-Saval and G. Barton, "Characterisation of quantum dot photoluminescence in polymer optical fibres", *18th ICPOF*, September 9-11, Sydney, Australia, paper S2_29, 2009.