Micro-structured Er^{3+}-Tm^{3+} co-doped tellurite fiber for broadband optical amplifier around 1550nm

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ABSTRACT

Micro-structured Er^{3+}-Tm^{3+} co-doped tellurite fiber with three rings of holes was fabricated using a soft glass drawing tower by a stack-and-draw technique. Amplified spontaneous emission (ASE) around 1550nm band were observed when pumped with both, 980nm and 790nm, lasers.

1. INTRODUCTION

Both micro-structured optical fibers and photonic crystal fibers (PCF), have shown great potential for application in several areas, specially for non-linear optics, supercontinuum generation, fiber sensors such as gas sensors and biochemical sensors. Each application demands a specific designed PCF. The first step in the fabrication of a PCF is the preparation of a pre-form with the desired structure which is then drawn down on a fiber-drawing tower greatly extending its length while reducing its cross-section. The silica-based PCF's pre-forms are usually made by stacking capillaries and rods by hand, which is known as stack-and-draw technique [1, 2].

The recent efforts to enhance more and more the bandwidth of a supercontinuum generation have driven the interest to materials other than silica such as soft-glass PCFs using extrusion process [3]. Tellurite glasses are better hosts than silica for rare earth doping due to its broader gain bandwidth, higher solubility and low cross relaxation. The emission band around 1550nm telecommunication window increases when tellurite glasses are doped with Erbium and Thulium ions simultaneously [4]. We recently reported a 187 nm emission bandwidth with a 15cm long Er^{3+} and Tm^{3+} co-doped tellurite core/clad standard fiber, pumped at 790 nm [5]. However, the PCF design flexibility can be used to enhance the Er^{3+}-Tm^{3+} optical amplifiers performance. White [6] studied the confinement losses for micro-structured optical fibers as function of the number of hole rings around the solid core to show that there is a better light confinement at the fiber core when the number of rings increases. On the other hand the PCF light guiding becomes more sensitive to defects. Therefore, only silica optical fibers made with high quality silica capillaries have been produced. The main difficulty to produce several periods PCF with soft-glasses is the abrupt viscosity variation with temperature that decreases the accuracy of fiber diameter control.

This letter reports the successful fabrication of micro-structured Er^{3+}-Tm^{3+} co-doped tellurite by the stack-and-draw technique with three rings of holes, and the demonstration of amplified spontaneous emission bandwidth around 1550nm of a 21 cm long fiber pumped at 790nm and 980nm pump lasers. So far only soft glass PCFs reported have used the extrusion technique.

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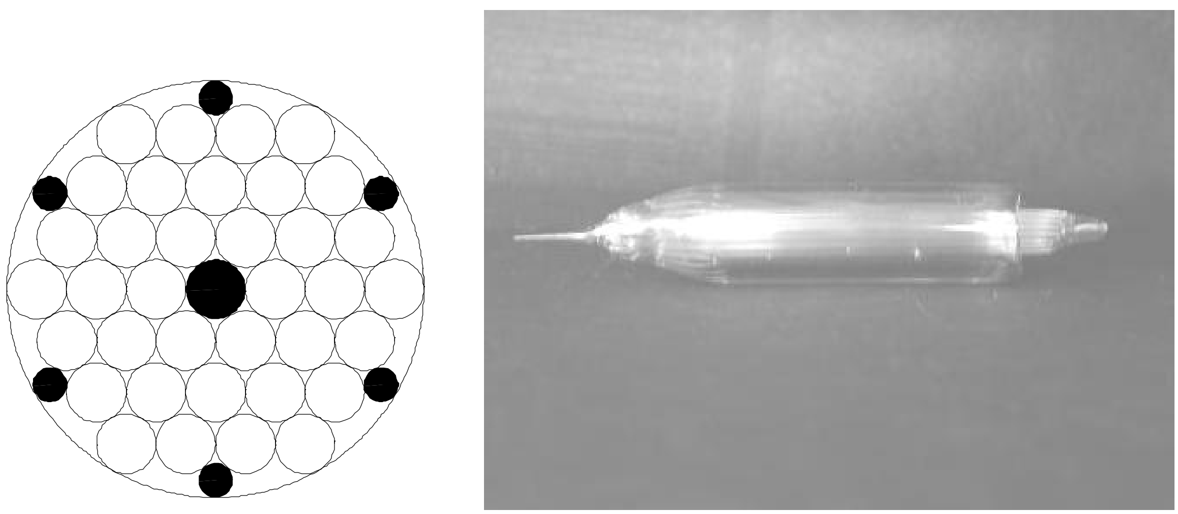
2. MICRO-STRUCTURED OPTICAL FIBER DESIGN AND FABRICATION

The tellurite glass preform was made by stacking thirty six capillaries arround an Erbium (7500 ppm wt%) and Thulium (5000 ppm wt%) co-doped tellurite central rod. The whole set was placed inside of an undoped tellurite glass tube with 6.3mm inner diameter (ID) and 12.15mm outer diameter (OD). The $71TeO_2$-$22.5WO_3$-$5Na_2O$-$1.5Nb_2O_5$ (%mol) Tellurite tubes with 12 cm length were obtained using the centrifugation process [7, 8]. The 0.9mm OD capillaries (with ID/OD ≈ 0.8) were drawn from 12.72 mm tubes (ID/ OD ≈ 0.81) and these were stacked, together with the central solid rod, to form the preform cross section shown in figure 1-(A). The capillaries were drawn using a Heathway draw tower at 200mm/min drawn speed, 1.0mm/min preform feed speed, 8.0 *l*/min N_2 gas flow and 505ºC furnace temperature carefully controled to avoid diameter variations during fabrication process. Figure 1-B shows the rest of the final preform after PCF drawing at the same Heathway tower at 2m/min drawing speed with furnace temperatures between 540 and 505 Celsius degrees and 7.5 *l*/min N_2 gas flow. The fiber was drawn at the left end of the preform. One can notice that the right end is also collapsed. The collapse of the preform ends was an important procedure to keep all the capillaries and central rod joined together.



(A) **(B)**

Fig. 1 Capillaries and rod stacked inside a 6.3mm tube diameter (A) and tellurite micro-structured preform (B), used to produce the optical fiber.

3. RESULTS AND DISCUSSIONS

Figure 2 shows the 190 μm external and 15 μm core diameters cross section of the tellurite Er^{3+} - Tm^{3+} co-doped fiber produced.

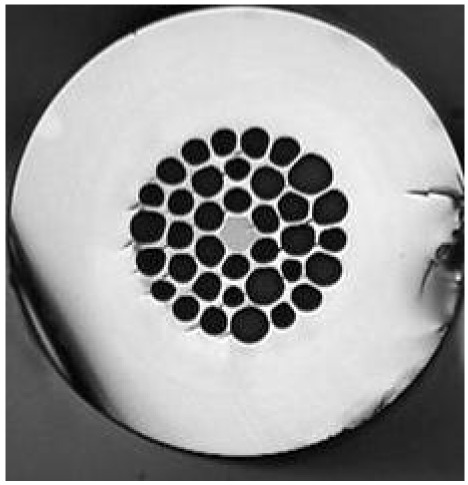


Fig. 2 Cross-section image of a micro-structured optical fiber fabricated using $71TeO_2$-$22.5WO_3$-$5Na_2O$-$1.5Nb_2O_5$ (%mol) tellurite glass. The cross-section shows three rings of holes.

Figure 3 shows the experimental setup for the ASE spectra acquisition pumped by a 790nm cw Ti:Sapphire laser [8]. The luminescence green light is observed along the whole fiber length between the objective lenses.

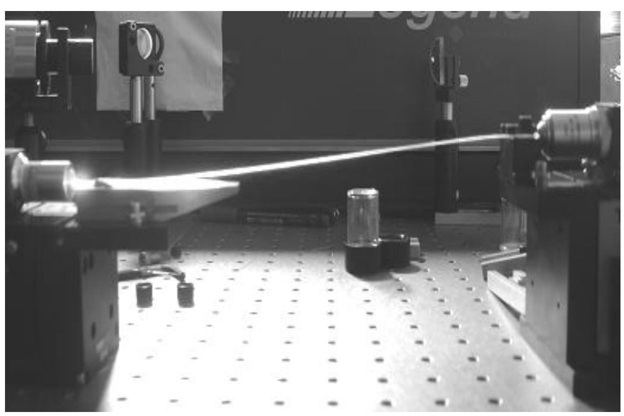


Fig. 3 Set-up experimental to ASE measurements

Figure 4 shows the ASE spectra obtained with the 21 cm long tellurite PCF pumped with 380 mW at 790nm of a cw Ti:sapphire laser, or with 120mW at 980nm of a diode laser, and collected with an Optical Spectrum Analyzer (Ando, model AQ-6315A) with 10nm resolution.

The main contributions for the ASE in (a) curve, excited with 980nm, comes from the Er^{3+} $^4I_{13/2} \rightarrow {}^4I_{15/2}$ transition around the 1550 nm band. On the other hand we also observed the Tm^{3+} $^3H_4 \rightarrow {}^3F_4$ (~1450 nm) band when the PCF is pumped with 380 mW at 790 nm (b) curve.

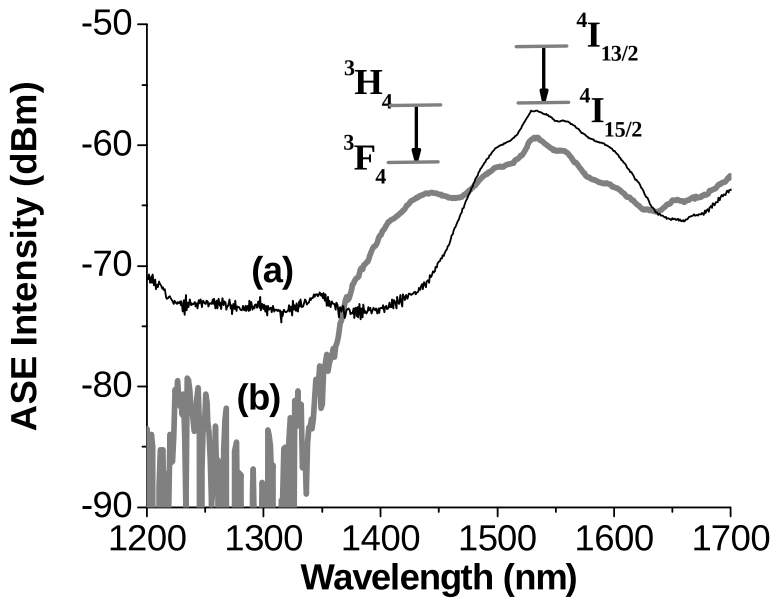


Fig. 4 (a) represents ASE spectra obtained for 980 nm pump laser and (b) curve for 790nm pump laser. In both cases the 21cm fiber length was preserved.

4. CONCLUSIONS

This work shows a successful fabrication of a micro-structured co-doped Er^{3+}-Tm^{3+} tellurite fiber with three hole rings made by the stack-and-draw technique. We did not used extrusion in any of the fabrication steps. The capillaries were drawn from tubes prepared by a centrifugation method.

5. ACKNOWLEDGMENTS

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