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Fabrication and Characteristics of Cr-Doped Fibers Employing Powder-in-Tube Technique

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Abstract: The fabrication of Cr-doped fibers (CDFs) using fiber drawing-tower combined with non-silica powder-in-tube (PIT) technique to achieve the active application of chromium ions in fiber is demonstrated for the first time. The fluorescence enhancement, transmission loss, and few-mode operation are disussed in the paper. The success in fabrication of CDFs with PIT method may open the possibility for utilizing CDFs as broadband fiber light source.

OCIS codes: (060.2280) Fiber design and fabrication; (060.2290) Fiber materials; (060.2320) Fiber optics amplifiers and oscillators.

1. Introduction

Recently, the Cr-doped silica fibers (CDFs) have been fabricated by the use of a drawing-tower method with rod-in-tube technique (RIT) [1-3]. The CDFs exhibited broadband emissions mainly in NIR to IR regions (800-1200 nm and 1100-1600 nm) and demonstrated a single-mode characteristic when the wavelengths of transmission light were longer than 1310 nm [3]. However, the characteristics of CDFs using drawing tower with RIT technique limited Cr-ion concentrations in CDFs. The concentration of Cr in Cr:YAG rod was low because of the resultant thermal expansion mismatch [4]. Therefore, a novel technique to increase the concentration of Cr-ions in the CDFs is necessary.

In this study, we fabricated and characterized CDFs by employing a drawing-tower method equipped with powder-in-tube (PIT) design. To characterize the CDFs, the refractive index, transmission loss, fluorescence spectrum and far-field pattern were measured. The fluorescence spectrum exhibited broadbands in NIR region (800-1300 nm). The result shows the PIT technique can increase Cr-ion concentration and improve the fluorescence intensity in the CDFs. This indicates that the CDFs using fiber drawing-tower equipped with PIT preform may be one step forward to fabricate high performance CDFs and then utilizing the CDFs as broadband fiber optical amplifiers and a broadband source for ultrahigh resolution optical coherence tomography (OCT).

2. Cr-doped fiber fabrication

A PIT method was used to assemble the Cr-doped powder/silica preform. The powder was CaO-Al_2O_3-$BaCO_3$-MgO-Cr_2O_3 [5]. The Cr-doped powder was poured into the center of the silica tube. The preform consisted of silica tube with outer diameter of 20 mm and inner diameter of 7 mm. Figure 1 shows a schematic diagram of a Cr-doped powder preform. The powder compositions melted in the silica tube during the drawing process. This process helped to eliminate the crucible contamination problems associated with core-glass fabrication before drawing fiber.

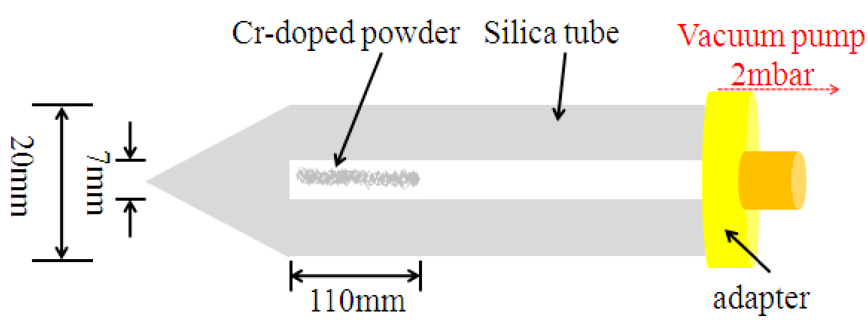

Fig.1. Schematic diagram of a Cr-doped powder preform.

The powder-filled silica tube were drawn into CDFs at approximately 2100 °C by employing the Nextrom

OFC20 fiber draw-tower equipped preform internal pressure control unit. At the temperature, the filled powders melt such that the cladding tube acts as a crucible. The drawing speed was set at around 5 to 15 m/min. The utilization of pressure control on preform helps for collapsing the cladding tube and maintaining circularity of core. There were dual layers of UV curable acrylate coating for maintaining pristine surface during take-up and storage.

Fig. 2. Photograph of the cleaved end with a 12 -μm-diameter core.

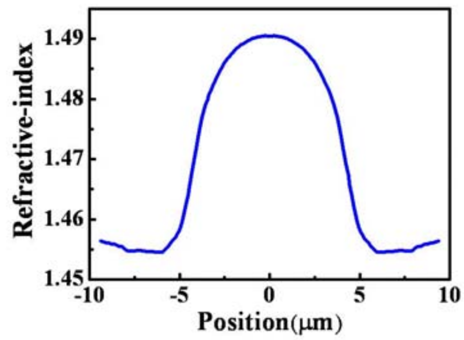

Fig. 3. The refractive index profile of the Cr-doped fiber.

3. Measurements and results

Few hundred meters of the CDFs has been drawn by using the drawing tower. Figure 2 shows a fiber end face with a 125-μm cladding and a 12-μm core. The refractive index was measured by using commercial equipment, EXFO NR9200, as shown in Fig. 3. The refractive-index profile of the CDF indicated the n_{core} = 1.49 and an index difference of Δ = 2.35%. Because of high temperature process, there was inter-diffusion between molten powder and silica. To measure CDF fluorescence intensity profiles, a Ti-sapphire laser was used as the light source. A 40x objective lens with a NA of 0.65 focused the laser beam to achieve 1-μm laterally spatial resolution. The fluorescence spectrum of an 8-cm CDF pumped by 720-nm light source with 0.2 W showed a broadband emission from 800 to 1300 nm. The peak emission is around 1000-nm and tails to 1300-nm, as shown in Fig. 4. The band of 800-1200 nm was dominated with Cr^{3+} ion and its power density was few nW/nm which showed a significant improvement around a hundred times compared with the previous work using RIT method [3]. Therefore, the CDFs may have the potential to be developed for the applications of broadband fiber optical amplifiers or a broadband source for ultrahigh resolution OCT.

For realizing the transmission loss of the CDF drawn by PIT design, a standard cutback technique was employed. A 120-cm-length CDF was spliced with a singlemode patch cord by a mechanical splicer for the measurement of the transmission loss. The average insertion loss of splicer is under 0.2 dB. Figure 5 shows the transmission loss were 0.7 dB/cm and 0.4 dB/cm at 1310 nm and 1550 nm, respectively. The peak around 1400nm was attributed to the absorption of OH-ion.

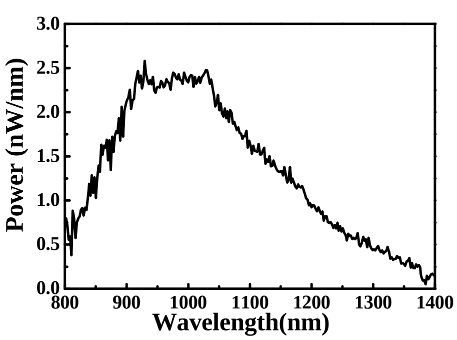

Fig. 4. The fluorescence spectrum of CDFs.

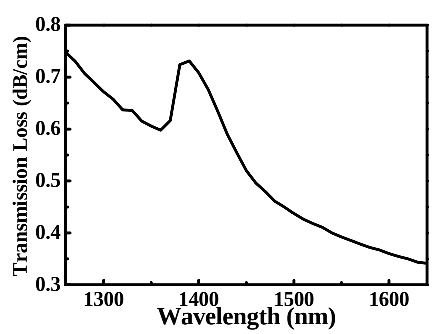

Fig. 5. The transmission loss of CDFs.

Figure 6 shows the measured far-field patterns of CDFs for various wavelengths. A 20-cm-length CDF was spliced with a single mode patch cord by mechanic splicer for the measurement of the far-field pattern. In order to eliminate the cladding effect, macro-bending with the facilitation of refractive index matching gel was employed during measuring process. From the measured far-field patterns, the far-field pattern indicated that a few-mode characteristic of CDF.

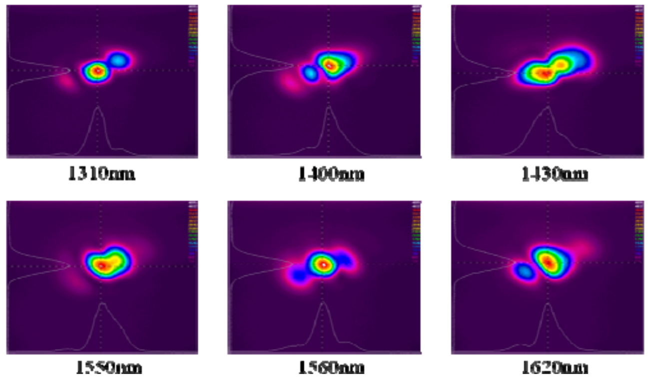

Fig. 6. The far-field patterns of CDF at different launching wavelength.

4. Discussion and Conclusion

In summary, a CDF with its emission wavelength extending in NIR region (800-1200nm) was fabricated and demonstrated by using a powder-in-tube (PIT) method in fiber drawing-tower technique. The CDFs had a 12-μm core and a 125-μm cladding. The far-field pattern measurements indicated the few-modes characteristic. The transmission loss was 0.7 dB/cm and 0.4 dB/cm at 1310 nm and 1550 nm, respectively. Although the transmission loss is high, the fluorescence intensity of CDFs is a significant improvement about a hundred times compared with the previous work [3]. The initial success in fabrication of CDFs promotes the potenial for utilizing the CDFs as new generation broadband fiber amplifiers, fiber laser application, and broadband source for ultrahigh resolution OCT. Improvements in reducing transmission loss, core diameter, and higher fluorescence are currently under investigation.

Acknowledgements

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