UV luminescence in Gd-doped silica and phosphosilicate optical fibres

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Abstract—**Gd^{3+}-doped silica and phosphosilicate fibers were pulled from preforms fabricated using the rod-in-tube technique and the solution doping technique, respectively. Ultraviolet (UV)-B luminescence from Gd^{3+} at around 312 nm given by Gd^{3+} $^6P_{7/2} \rightarrow {}^8S_{7/2}$ transition were observed under deep UV excitations pumping to the Gd^{3+} ^6D_J, ^6I_J, and $^6P_{J=5/2,3/2}$ energy levels.**

Keywords-gadolinium; photoluminescence; ultraviolet; fiber

I. Introduction

Fiberized light sources exhibit excellent beam quality and power handling capabilities. Silica fibers are the favorite hosts for lasing ions as they tend to have high temporal stability and mechanical strength as well as strong chemical and radiation resistance. They are compatible with existing silica-based optical fiber components and can be transparent in the ultraviolet (UV) [1]. Fiber lasers operating in the near infrared and visible have relied on rare earths, mostly on Yb^{3+}, Er^{3+} and Tm^{3+}. Extension to the UV would benefit medical and industrial applications, where, at present, gas lasers, lamps, diodes or sources based on nonlinear harmonic generations are mostly used [2]-[5]. Here, we investigated the UV-B luminescence emissions from silica fibers doped with trivalent gadolinium ions, Gd^{3+}, with an energy gap of ~32000 cm^{-1} between the ground state and the first excited level (Fig.1).

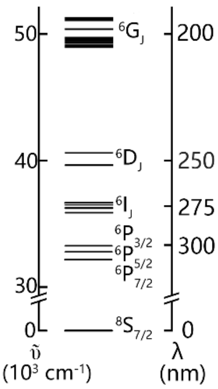

Figure 1. Schematic of the Gd^{3+} energy levels (adapted from reference [6] and [7]). $\tilde{v}$ and λ are the wavenumbers and wavelengths of the photons emitted in the transitions to the ground level.

II. Sample Preparation

Two types of fiber core host materials, i.e., phosphosilicate and pure silica, were investigated. The phosphosilicate sample had a pure silica cladding and a Gd doped phosphosilicate core fabricated using the modified chemical vapor technique (MCVD) and the solution doping technique [8] with vapor-phase $SiCl_4$ and $POCl_3$ precursors and $GdCl_3{\cdot}6H_2O$ methanol solution. The average Gd^{3+} concentration in the core measured using energy-dispersive X-ray spectroscopy (EDX) was ~1170 ppm. The preform was pulled into a fiber at temperature above 2000 ºC. The fiber cladding and core diameters were 5.8 μm and 125 μm, respectively.

The Gd^{3+} doped silica sample had a silica core fabricated by sol-gel [9] and a fluorosilicate cladding added via rod-in-tube technique. Characterization of the sol-gel rod had been previously presented elsewhere [10]. The rod without the cladding was pulled into fiber canes for the PL measurements.

III. Gadolinium Absorptions

Absorption associated to Gd^{3+} doping in the phosphosilicate fiber was observed when pumping with a broadband deuterium lamp source (BDS130, BWTEK) (Fig. 2). The propagation loss measured via the cutback method shows relatively narrow peaks at the wavelengths λ=301.4 nm, 306.3 nm and 311.9 nm (Fig. 2), attributed to the Gd^{3+} transitions from the fundamental ($^8S_{7/2}$) to the ^6P_J multiplet levels. High losses at short wavelengths are mostly related to defects [11], low OH concentration and phosphosilicate bandgap [12].

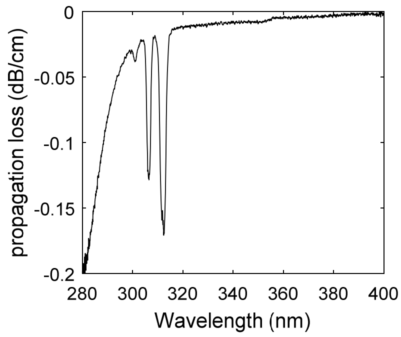

Figure 2. Propagation loss of the phosphosilicate fiber.

IV. PHOTOLUMINESCENCE

The PL and the photoluminescence excitation (PLE) spectra of a disk cut from the phosphosilicate preform, a bundle of phosphosilicate fibers and a stack of silica fiber canes were recorded using Horiba Fluorolog-3 spectrofluorometer equipped with a Xenon excitation lamp. To improve the signal-to-noise ratio, light was incident on the sides, which have the highest core to cladding aspect ratio.

UV-B emission originating from the Gd^{3+} $^6P_{7/2} \rightarrow {}^8S_{7/2}$ transition was observed at λ=311.7 nm from the phosphosilicate preform disk. PLE peaks were recorded at λ_{ex}=243.7 nm, 245.7 nm and 251.9 nm, when pumping into the ^6D_J levels; at λ_{ex}=272.6 nm, 275.2 nm and 278.3nm, when pumping into the ^6I_J levels; and at λ_{ex}=304.0 nm, when pumping into the $^6P_{5/2}$ levels, respectively (Fig. 3, red).

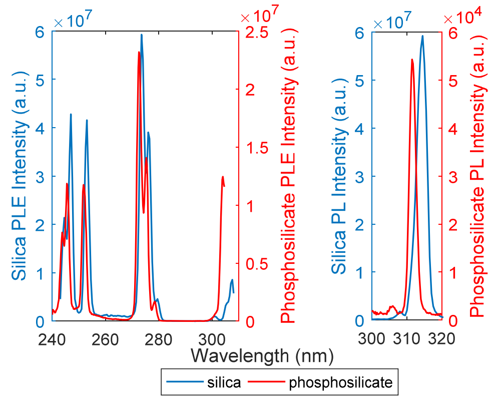

Figure 3. PL and PLE spectra of silica (λ_{ex}~274, λ_{em}~314 nm) and phosphosilicate (λ_{ex}~272.5, λ_{em}~312 nm) fibers.

These transition features a spin change and shows linewidth of $\Delta\lambda$~2.5 nm (FWHM) in the PL spectrum. Comparison with results from the Gd^{3+}-doped phosphosilicate fiber (Fig. 4) suggests that these wavelengths were maintained after the thermal treatment during the fiber pulling process.

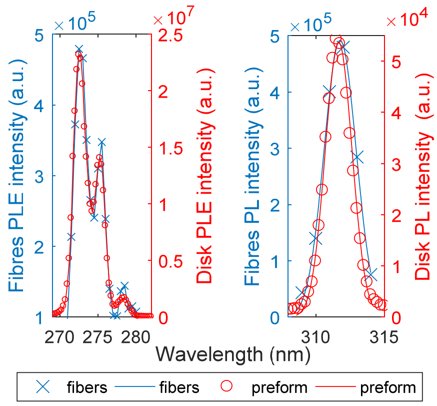

Figure 4. PL (λ_{ex}~272.5) and PLE (λ_{em}~312 nm) spectra of phosphosilicate preform disk and fibers.

Similar results were recorded from the Gd^{3+}-doped silica fiber cane, with a wavelength shift of $\Delta\lambda$~1.5 nm with respect to the phosphosilicate samples (Fig. 3, blue). The peak emission wavelength, 314 nm, was unchanged, with respect to that of the preform rod [10].

V. CONCLUSIONS

UV-B PL emissions at λ=311.7 nm and 314 nm from phosphosilicate and silica fibers, respectively, doped with Gd^{3+} are reported. The absorption and emission wavelengths were not affected by a thermal treatment during a fiber pulling at a high temperature. A spectral shift of $\Delta\lambda$~1.5 nm caused by the difference in the host materials was recorded.

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