Infrared Luminescence Enhancement by UV-Irradiation of H_2-loaded Bi-Al-doped Fiber

C. Ban(1), L.I. Bulatov(2), V.V. Dvoyrin(2), V.M. Mashinsky(2), H.G. Limberger(1), E.M. Dianov(2)

(1) Ecole Polytechnique Fédéral de Lausanne, School of Engineering, Advanced Photonics Laboratory, CH-1015 Lausanne, Switzerland, hans.limberger@epfl.ch
(2) Fiber Optics Research Center, Russian Academy of Sciences, 38 Vavilov Street, 119333 Moscow, Russia, lenar@fo.gpi.ru.

Abstract *ArF excimer laser irradiation of H_2-loaded fibers increases the intensity of both the 1130 and 1390 nm fluorescence in Bi-Al-doped silica fiber by 18 dB and >16 dB.*

Introduction

Bismuth doped silica glass shows broadband fluorescence and gain in the 2nd and 3rd telecommunication window. Fujimoto et al. were the first to report infrared luminescence[1] and amplification[2] around 1300 nm in bismuth doped silica glass. Optical fibers with bismuth as dopant were first reported by Haruna et al.[3] and Dvoyrin et al.[4] in 2005. Absorption bands centered at 500, 700, 800 and 1000 nm were observed.[3-5] Luminescence was observed around 750 and 1100 nm under visible light pumping at 1150 nm under 1000 nm pumping,[4] and at 1430 nm under 1343 nm pumping in Bi-Al-doped silica fiber.[6] Fiber laser generation using Bi-doped fiber was firstly realized in 2005.[7] Research effort focuses on fibers and glasses with different glass composition to increase the efficiency of IR fluorescence and to broaden its spectral range.[8] Recently, Peng et al. reported a strong increase in 500 nm absorption and a ~6-fold increase in infrared luminescence due to Ti:Sapphire femtosecond laser irradiation in bismuthate glass.[9] The observation was attributed to the photoinduced reduction of Bi^{3+} to Bi^{+} species. Later Bulatov et al. showed the possibility of the growth of red and infrared luminescence intensity of bismuth centers in aluminosilicate optical fibers under the exposure to 514, 532 and 244 nm laser radiation. Hydrogen loading followed by the laser irradiation resulted in further increase of infrared luminescence.[10]

In this work we report about absorption and luminescence changes in Bi-Al-doped silica fibers subject to pulsed UV irradiation at 193 nm. Results are compared for pristine and hydrogen loaded fibers as well as for UV irradiation of these fibers. The main result is that infrared luminescence of Bi-Al-doped silica fibers is enhanced due to UV irradiation by about 9 dB for a pristine fiber and by about 18 dB for fibers previously loaded with hydrogen.

Experimental procedure

The investigated fiber has a SiO_2 cladding and a Bi-Al-doped silica core. The preform was prepared using the modified chemical vapor deposition technique. The bismuth and aluminum oxide concentrations were <0.02 at.% and 2 mol.%, respectively. Aluminum was incorporated as a dopant in the preforms to provide Bi luminescence and to raise the core index. The cut-off wavelength was around 1.1 µm. A 10 cm section of Bi-Al-doped fiber was illuminated uniformly by UV light at 193 nm. Irradiation was performed on pristine fiber as well as on hydrogen loaded fiber. Fiber was H_2-loaded for 19 days at 150 bar at ambient temperature. The fluence per pulse was 134 mJ/cm^2 and the total dose was 6.1 kJ/cm^2 for irradiation of the pristine fiber. For the H_2-loaded fiber fluence and total dose were 137 mJ/cm^2 and 9.2 kJ/cm^2, respectively. The repetition rate was 10 Hz.

From previous photosensitivity investigations and fiber grating inscription of this Bi-Al-doped fiber, the induced index change is estimated to be 1×10^{-4} for the irradiated pristine sample and 1.2×10^{-3} for the irradiated H_2-loaded fiber.[11, 12]

Absorption measurements were performed from 360 to 1700 nm using the cut-back method. The infrared luminescence were investigated from outer surface of the fiber. The fluorescence light was collected perpendicular to the axis of the Bi-Al-doped fiber using a multimode fiber with a core diameter of 1 mm and measured by an optical spectrum analyzer. For excitation an ytterbium fiber laser emitting at 1053 nm was used to pump the emission bands situated around 1100 nm and a fiber Raman laser emitting at 1357 nm to pump the bands situated at 1390 nm. The pump power used was 3 W and 500 mW for the Yb and Raman fiber laser, respectively. To reduce losses and increase stability the fiber was spliced to the Yb (or Raman) fiber laser.

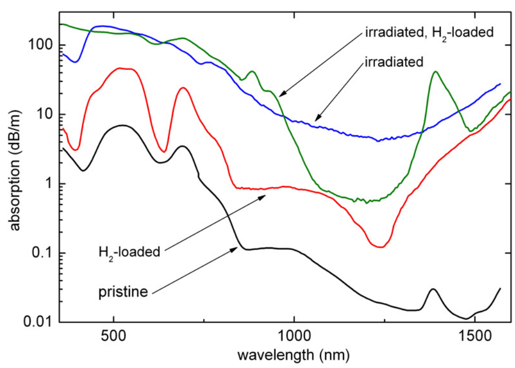

Fig. 1: Absorption spectra of pristine, irradiated, H_2-loaded, and irradiated H_2-loaded Bi-Al-doped silica fiber.

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Results

The measured absorption spectra of the *pristine*, the UV irradiated, the hydrogen loaded, and the UV irradiated H_2-loaded fiber are presented in Fig. 1. The pristine absorption curve exhibits peaks situated at 500, 700, 800, 1000 and 1400 nm. The 1400 nm band is screened by the narrow band at 1390 nm which is attributed to OH-groups. After *hydrogen loading* all the bands observed in pristine fiber are still present, the OH-band seems to be indistinguishable. *Irradiation of the pristine fiber* increases the absorption compared to pristine and to H_2-loaded fiber. The dip situated at 640 nm for pristine and H_2-loaded fiber disappeared due to the appearance of a new band. The *irradiated H_2-loaded fiber* shows an increased absorption at 400 nm and a pronounced OH absorption which is increased by 41.7 dB (factor 15000) compared to the pristine fiber. Note that due to short fiber length the signal to noise ratio in the 1000 to 1350 nm region for the *irradiated fiber* and the *irradiated H_2-loaded fiber* are too low for a reliable interpretation. To identify the transitions shaping the absorption spectrum of each fiber, decomposition into *Gaussian* bands was performed assuming that inhomogeneous broadening dominates in glass. Similar to the results reported by Bulatov et al. three

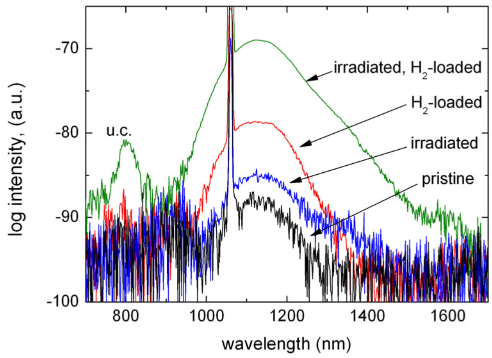

Fig. 2: Side luminescence spectra of pristine, irradiated, H_2 loaded and irradiated H_2 loaded Bi-silica fiber under 1053 nm excitation (3 W).

modifications of one and the same active bismuth center could be identified in this fiber.[13] The decomposition (not shown here) emphasizes the appearance of three new absorption bands in both irradiated samples suggesting that irradiation leads to the creation of a new absorption center.

Figure 2 shows the side-luminescence spectra of pristine, irradiated, H_2-loaded and irradiated H_2-loaded fiber. The peak at 1053 nm corresponds to the Yb pump laser. A luminescence band is observed at 1130 nm with 140 nm bandwidth. Its position does not change with treatment. As the fiber has a very small Bi concentration, the maximum of the IR luminescence of the pristine fiber is about 7 dB above the detection limit of the apparatus used (~-95 dB). UV irradiation increases the fluorescence intensity by 2 dB, and hydrogen loading by 8 dB as compared with pristine fiber. The UV irradiation of the H_2-loaded fiber leads to a strong increase of 18 dB (factor 63) of luminescence compared to the pristine fiber. In addition, an upconversion band was observed at 800 nm with an intensity that is -12 dB below the IR intensity. Not shown here is an additional green upconversion band.

Figure 3 shows the increase of the 1390 nm fluorescence due to the UV irradiation of the H_2-loaded fiber using a pump power of 0.5 W at 1357 nm. The 1130 nm-band is excited by the remaining power of the Raman pump laser. No fluorescence was observed in the pristine and H_2-loaded fiber.

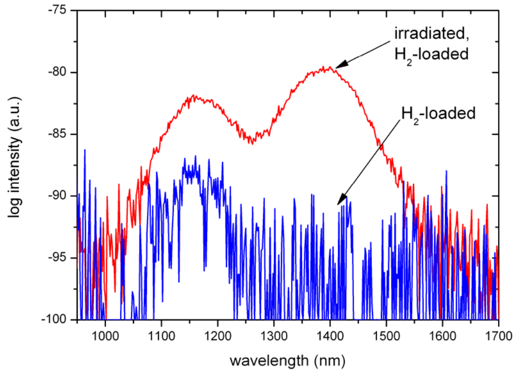

Fig. 3: Side luminescence spectra of H_2-loaded and irradiated H_2-loaded Bi-doped silica fiber under 1357 nm excitation (3W).

Conclusions

Absorption and luminescence increase due to UV irradiation, H_2-loading, and UV irradiation of H_2-loaded fiber was observed. The irradiated H_2-loaded sample shows huge increase of the 1130 and 1390 nm luminescence intensity under 1053 and 1357 nm pumping. This luminescence enhancement seems to be attributed to an increase of the active bismuth centers concentration.

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