Green Upconversion Emissions of an Erbium-Doped Fiber Pumped by Infrared Lasers

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(NSC 95-2112-M-005-014-MY3, NSC 97-2112-M-415-002-MY3)

ABSTRACT

We pumped an erbium-doped fiber by an 800 nm femtosecond laser and a 980 nm diode laser, respectively. The intense green upconversion emissions have been observed in our measurements and their fluorescence spectra were detected.

INTRODUCTION

Upconversion is the generation of one photon with a higher energy from at least two lower energy photons through the process of multi-photon absorption or excited state absorption. Recently, the green upconversion emission of rare-earth-ion Er/Dy codoped materials pumped by an 800 nm infrared femtosecond laser has attracted again many research interests [1].

The green emission of Er^{3+} ions under 800 nm excitation is attributed to excited-state absorption through a multi-step process. As shown in the energy-level diagram [Fig. 1(a)] of erbium ions [2], the electrons in Er^{3+} ions are first pumped to the $^4I_{9/2}$ state, after which they decay nonradiatively to the metastable $^4I_{13/2}$ state. Then they are excited successively by other pump photons to the $^2H_{11/2}$ and $^4S_{3/2}$ thermalized states. After that, they decay to the ground state $^4I_{15/2}$ with green emission [2].

Moreover, the observations of blue, green, red, and near infrared fluorescence from an erbium-doped fiber pumped by a 1.48 μm laser diode and a 1.51 μm femtosecond laser have been reported [3,4]. Violet upconversion emission of an erbium-doped fluoride fiber pumped with a red dye laser from the $^2P_{3/2}$ state was also found to be due to a three-photon excitation process [5].

There are many fascinating applications using the green upconversion emission of an erbium-doped fiber, for example, a fiber-optic temperature sensor which is based on the temperature-dependent intensity ratio of two green fluorescence bands (transitions from $^2H_{11/2}$ and $^4S_{3/2}$ energy levels to the ground state $^4I_{15/2}$) [2]. These research results have increased the diversity of the study in the green upconversion emission of an erbium-doped fiber.

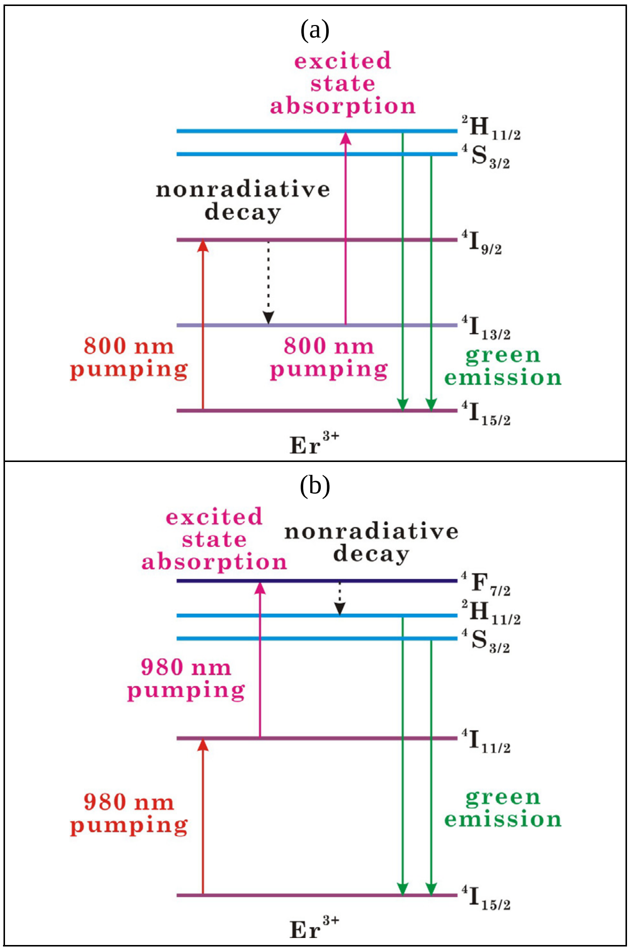


Fig. 1. The energy-level diagrams of erbium ions and their associated electron transition processes in generating green upconversion emission under (a) 800 nm and (b) 980 nm infrared laser excitations.

EXPERIMENTAL SETUPS and RESULTS

A. Pumped by an 800 nm Femtosecond Laser

One 800 nm Ti:sapphire femtosecond laser delivering ~100 fs mode-locked pulses was focused into an erbium-doped fiber with a 15 cm length by a 20X microscope objective (Fig. 2). An optical spectrometer was used to detect the fluorescence spectrum (Fig. 3) of the visible upconversion emission emerging out of the pumped erbium-doped fiber.

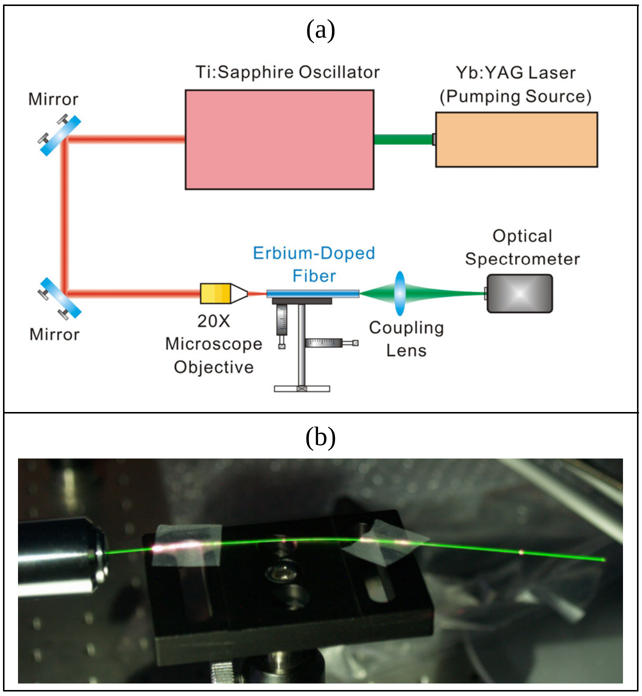
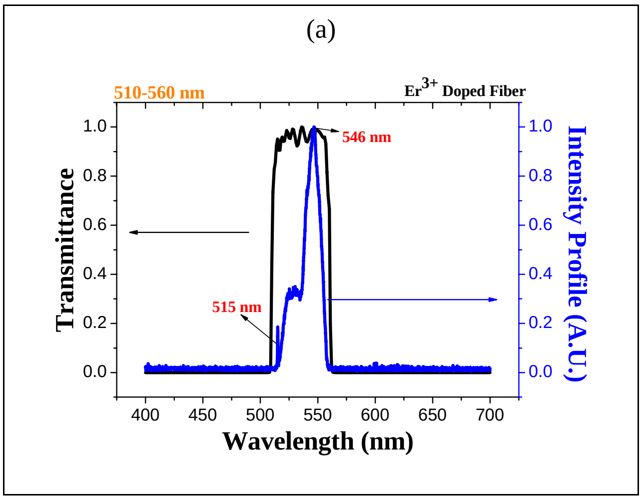


Fig. 2. (a) The configuration of the experimental setup. (b) The observed intense green upconversion emission of an erbium-doped fiber under 800 nm excitation.



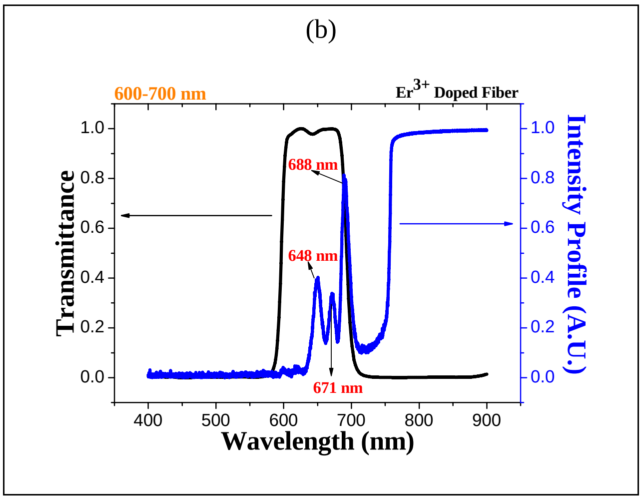
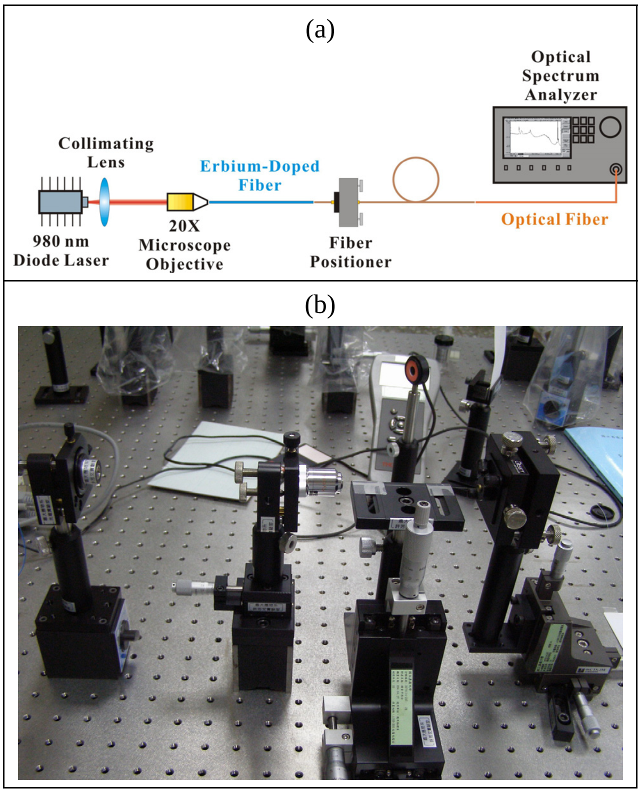


Fig. 3. The measured (a) green and (b) red fluorescence spectra of an erbium-doped fiber under 800 nm excitation by a band-pass filter ranged at 510-560 nm and 600-700 nm, respectively.

B. Pumped by a 980 nm Diode Laser

We have also tried another pumping source, a 980 nm continuous-wave diode laser, to test the upconversion emission of an erbium-doped fiber (Figs. 4 and 5).



(c)

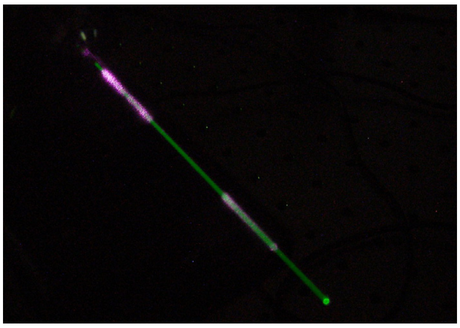


Fig. 4. The (a) configuration and (b) photograph of the experimental setup. (c) The observed green upconversion emission of an erbium-doped fiber under 980 nm excitation.

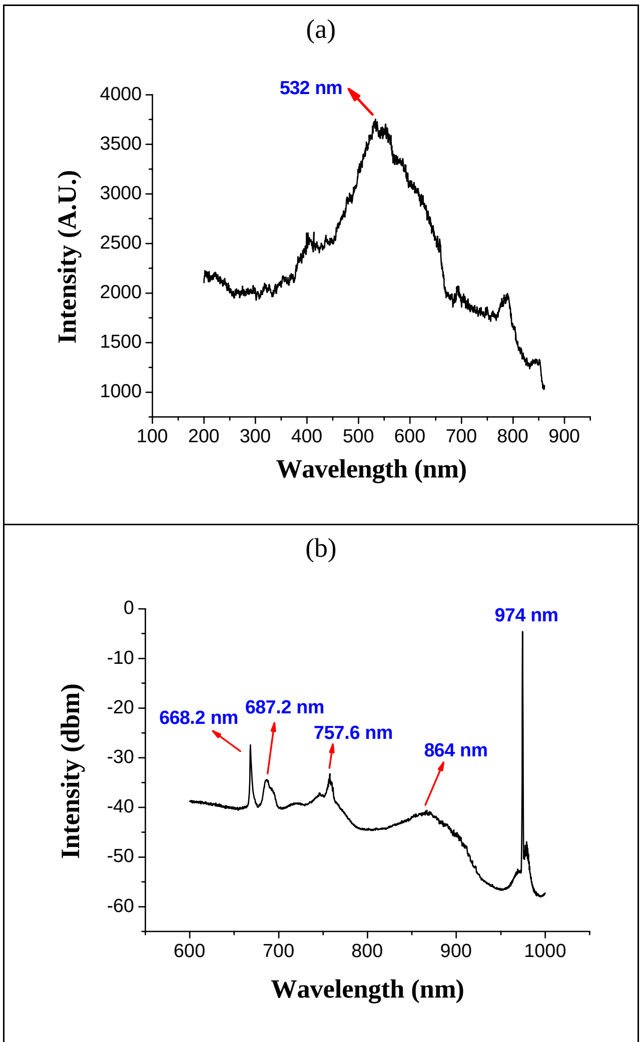


Fig. 5. The measured (a) green and (b) red-infrared fluorescence spectra of an erbium-doped fiber under 980 nm excitation.

CONCLUSION

We have achieved observing the visible upconversion emissions of an erbium-doped fiber under 800 nm and 980 nm infrared laser excitations. A green upconversion erbium-doped fiber laser [6] with a high-quality transverse mode output is being established.

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