High Efficiency Cascade Fiber Laser at 2.8 μm

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Diode-pumped erbium-doped fluoride glass (Er:FG) fiber lasers operating near the water absorption peak have a potential use in medical [1] and spectroscopy [2] applications. However, their efficiency is generally limited to the maximum Stokes efficiency limit of ~35%. Until now, the only way demonstrated to exceed this limit takes advantage of an energy transfer upconversion process (ETU). Nonetheless, such ETU processes are only efficient in heavily doped fibers which lead to high heat load per unit length of the fiber, thus limiting the power scaling potential of such an approach. To date, the highest slope efficiency of 35.4%, slightly exceeding the Stokes limit, was reported through ETU with a 7 mol. % Er^{3+}:FG fiber laser emitting near 2.8 μm [3].

In this work, we present a diode pumped passively-cooled Er:FG cascade fiber laser operating at 2.8 μm and 1.6 μm with a maximum slope efficiency of 40% at 2.8 μm with respect to the absorbed pump power at 980 nm. The schematic of the laser setup is shown in Fig. 1a. A 7 m length of 1 mol. % Er^{+3} doped FG fiber was used as an active medium and pumped by two combined 30W multimode diodes operating around 980 nm. As an input coupler for both wavelengths, a highly reflective dichroic mirror (HR-DM) having a reflectivity of 80% at both 1.6 μm and 2.8 μm and a transmission of 90% around 980 nm was used. Fresnel reflection from a straight cleaved end face was used as the output coupler (OC) for the 2.8 μm wavelength. As for the 1.6 μm OC, a fiber Bragg grating (FBG) centered at 1.613 μm and having a maximum reflectivity of 87% μm was written directly in the core of Er:FG fiber using a femtosecond laser. A residual pump stripper (RPS) was made near the end of the cavity by recoating a section of the fiber. In order to evaluate the effect of the 1.6 μm OC reflectivity on the 2.8 μm transition efficiency, experiments were performed at different decreasing OC reflectivities by thermally annealing the FBG.

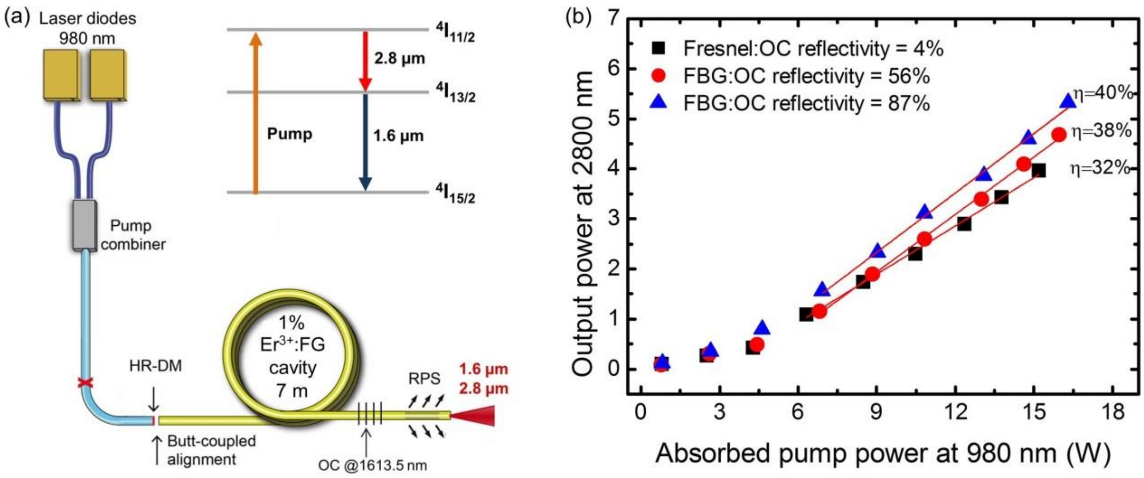

Fig. 1 a) Experimental setup of the cascade laser operating at 2.8 μm and 1.613 μm. The cavity is based on a 7 m gain fiber and includes: FBG output coupler at 1.6 μm; HR-DM, highly reflective dichroic mirror at both 1.6 μm and 2.8 μm; RPS, residual pump stripper; the inset shows a partial energy diagram of erbium ions with pump and laser transitions. b) Measured output power at 2800 nm with respect to absorbed pump power at 980 nm for different 1.6 μm OC reflectivities.

As shown in Fig. 1b, when the reflectivity of the 1.6 μm OC increases, the slope efficiency at 2.8 μm also increases with respect to absorbed pump power at 980 nm increases, suggesting that an efficient recycling process promotes the ions back to the 2.8 μm upper laser level through reabsorption of the 1.6 μm signal. At the highest 1.6 μm OC reflectivity, we achieved a slope efficiency of 40% which is significantly higher than the theoretical Stokes limit. The origin of such efficient recycling process as well as the potential for power scaling to the 100W level near 2.8 μm will be discussed.

References

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