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High-power and highly-efficient laser operation of Tm^{3+}:Ho^{3+}-codoped silica fiber lasers emitting at 2.1 µm and 2.2 µm

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Efficient high-power lasers emitting in the 2.1 µm to 2.2 µm wavelength range are of increasing interest for applications like mid-IR nonlinear frequency conversion or LIDAR, taking advantage of a broad atmospheric transmission window. To emit at wavelengths beyond 2.1 µm, Ho^{3+}-doped fiber lasers (HDFL) are predestined due to their matching emission cross-sections. However, power scaling within this wavelength region turns out to be quite challenging. Inefficient laser operation attributed to pair-induced quenching is leading to complex Tm^{3+}-doped fiber laser (TDFL) pumped setups. Despite a quite promising theoretical quantum defect of less than 10 %, slope efficiencies of this Ho^{3+}-stage are limited to 50-57 % for high laser output powers [1,2].
We present our recent progress in power scaling of alternative Tm^{3+}:Ho^{3+}-codoped silica fiber lasers, especially at emission wavelengths beyond 2.1 µm [3]. We show that high-power laser operation at these wavelengths can be more efficient as in-band pumped high-power Ho^{3+}-fiber lasers with the advantage of a much simpler setup using direct 79X nm diode pumping. Realizing a tunable setup by using a diffraction grating, a 200-nm wavelength span from 1990 nm to 2190 nm is covered with output powers above 10 W. This indicates the high potential for stable high-power laser operation for these wavelengths. Using a volume Bragg grating (VBG) centered at 2.1 µm as a high reflector, stable power scaling at 2.1 µm is established with a maximum output power of 262 W and a slope efficiency of 49 %. The left-hand side of figure 1 shows the according laser output power versus incident pump power.

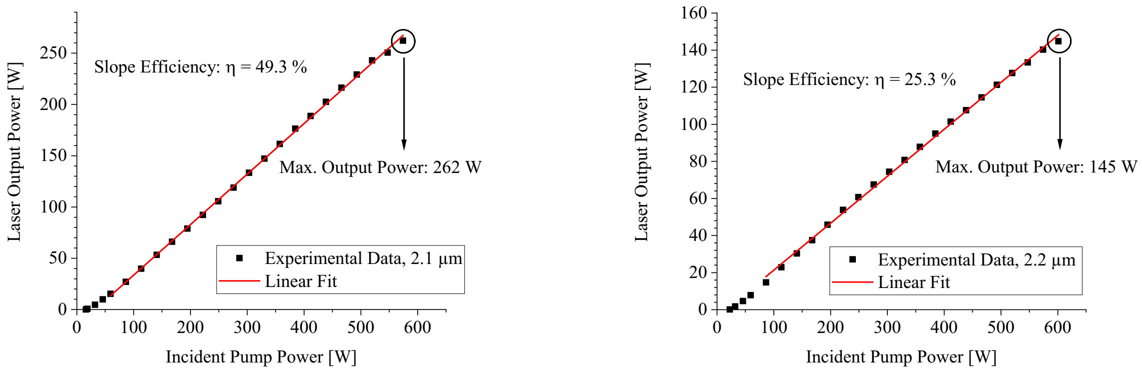

Figure 1: Laser output power versus incident 79X nm pump power of the Tm^{3+}:Ho^{3+}-codoped fiber laser at an emission wavelength of 2.1 µm (left-hand side) and at an emission wavelength of 2.2 µm (right-hand side).

A special challenge is the laser operation at an emission wavelength of 2.2 µm. At this wavelength, the emission cross-sections are vanishingly small for the Ho^{3+}-ions, the silica host shows increased absorption due to the uprising intrinsic IR-absorption and residual OH-contamination in the fiber. Nevertheless, using a VBG centered at 2.2 µm, the Tm^{3+}:Ho^{3+}-codoped fiber laser delivers up to 145 W at 2.2 µm (figure 1, right-hand side), increasing the current power record at this wavelength by more than one order of magnitude [4].

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