Order-of-magnitude power enhancement of an Er^{3+} 2.7-µm ZBLAN laser utilizing lifetime quenching by energy transfer to Pr^{3+}

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In recent years, there have been enormous research efforts to improve the performance of lasers emitting around 3 µm mainly because of their potential applications in medicine. The erbium-doped ZBLAN fiber is a promising candidate for the construction of a compact and efficient all-solid-state laser emitting on the transition at 2.7 µm (Fig. 1). However, a high excitation density with the consequences of pump excited-state absorption (ESA) can lead to output-power saturation in the fiber laser. This saturation was overcome in a cascade lasing regime and 150 mW of output power was achieved under Ti:sapphire pumping at 791 nm [1].

Here, we investigate experimentally a theoretical proposal to scale the output power of the Er^{3+} 2.7-µm fiber laser to the 1-W region [2]: Ground-state bleaching, large excitation of the Er^{3+} $^4I_{11/2}$ and $^4I_{13/2}$ laser levels, and consequent ESA losses are avoided by an active reduction of the excitation density due to a Förster-Dexter-type energy transfer from the Er^{3+} $^4I_{13/2}$ lower laser level to the $^3F_3$ level of a Pr^{3+} codopant and subsequent fast multiphonon relaxation of the Pr^{3+} ion (Fig. 1). With concentrations of 35000 ppm mol. Er^{3+} and 3000 ppm mol. Pr^{3+}, the Er^{3+} $^4I_{13/2}$ lifetime in ZBLAN is quenched from 8.7 ms to less than 300 µs [3].

Utilizing this approach, we demonstrate 1.7 W of output power in a near transverse-fundamental mode and 17% slope efficiency at 2.71 µm (Fig. 2) from an erbium ZBLAN fiber pumped at 790 nm by 22 W from a diode source. This result represents more than an order-of-magnitude improvement in output power over previous work. The double-clad fiber consisted of a circular core of 15 µm diameter and a rectangular inner cladding of 100×200 µm^2 [4]. Since also ESA from the $^4I_{11/2}$ upper laser level is avoided due to the threshold condition for the laser levels, further power scaling seems possible by pumping at 980 nm directly into $^4I_{11/2}$.

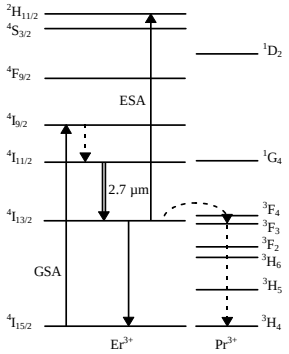

Fig. 1: Partial energy-level diagram of Er^{3+} and Pr^{3+} in ZBLAN glass indicating the processes which are relevant for the operation of the laser at the Er^{3+} transition $^4I_{11/2} \rightarrow {}^4I_{13/2}$.

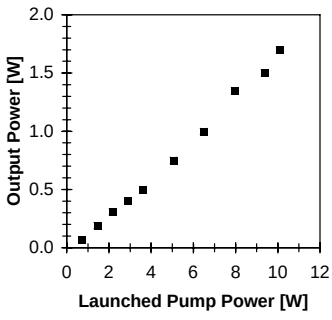

Fig. 2: Output power at 2.7 µm versus launched pump power at 790 nm of the diode-pumped ZBLAN fiber laser

References

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