Experimental and numerical study of a monolithic single-oscillator thulium-doped fiber laser in continuous-wave regime

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The atmospheric transmission window around 2 µm makes this wavelength compatible with military applications that require propagation over long distances as telecommunications, LIDARS or directive infrared countermeasures. In order to generate high powers (several hundreds of watts) with a high beam quality, rare-earth doped fiber lasers are particularly attractive. Furthermore, these military applications imply using compact, robust and efficient architectures and it appears that monolithic single-oscillator all-fiber laser sources are perfect candidates. The highest power reported from a single-oscillator thulium (Tm^{3+}) doped fiber laser source pumped at 793 nm has been reported by Walbaum *et al.* in 2016, with 567 W of output power at 1.94 µm and with 49.4 % slope efficiency [1]. The pump and signal wavelengths are defined with respect to both the absorption and emission cross sections of the thulium ion. Similar architectures have also been developed to emit above 2.05 µm with holmium (Ho^{3+}) ions, such as Ho^{3+}-doped fibers pumped at 1.95 µm [2] or Tm^{3+}, Ho^{3+}-co-doped fibers pumped at 793 nm [3].

Rate equations, describing the population variations of the Tm^{3+} energy levels [4], are a good way to theoretically describe the laser dynamics, taking into account the different cross sections and the opto-geometric parameters of the laser cavity. In this presentation, we will demonstrate the application of the rate equations to the study of a monolithic single-oscillator thulium-doped fiber laser. The results will also be compared to the experimental measurements.

The single oscillator is described in Fig. 1a. It consists of a 4.89-m silica double-clad fiber (*iXblue Photonics*) with a 20-µm Tm^{3+}-doped core (absorption at 793 nm: 8.42 dB/m), surrounded by a 60-µm germanium-doped pedestal and a 250-µm octagonal-shaped cladding. The fiber is pumped on both sides by a total of 540 W of pump power at 793 nm and placed in a Fresnel cavity, that is delimited on both sides by a 0°-cleaved angle which reflects 4% of the intracavity light. In this configuration, the laser exhibits two outputs. In the following, we consider the sum of these two outputs, both for numerical and experimental analysis.

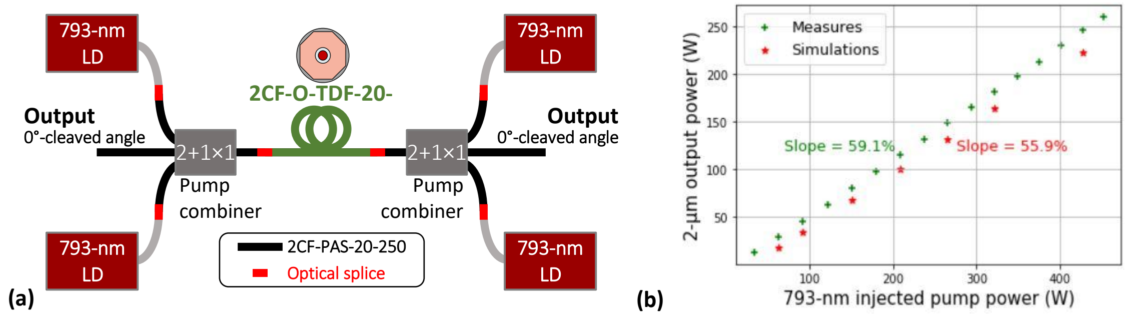

Fig. 1 (a) Schematic of the experimental setup of the Fresnel-cavity configuration of the monolithic single-oscillator thulium-doped fiber laser source. LD: laser diode ; (b) Simulated and measured 2-µm output power versus injected 793-nm pump power.

Fig. 1b shows both simulated and measured output powers versus 793-nm pump powers of the Fresnel cavity. Experimentally, the laser sources exhibited a total power of 260 W, as the sum of its two outputs (slope efficiency: 59 %). The numerical simulations gave a slope efficiency a little bit lower (55 %). We assume that experimental and numerical results did not fit exactly because the first version of the algorithm took into account only a couple of wavelengths (793.0 nm for pump and 2020.0 nm for signal). A new version of the algorithm with a dependence on wavelength is in progress and will be presented during the conference. It will allow to simulate a standard laser cavity by replacing one of the 4-% Fresnel reflections of the current cavity by the measured reflectivity spectrum of a high-reflectivity fiber Bragg grating. Future research activities will be devoted to increase the pump power injected into the single oscillator. It will impose to implement a new optic fiber able to handle kW-class power that will be featured in our numerical tool.

References

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