High Power Pulse Amplification in Tm-Doped Fiber

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Abstract: We report >20W of average output power at 1.995μm from a pulsed Tm-doped fiber amplifier system operating at 100kHz. Pulse energies of >325μJ have been generated at 50kHz with 13ns pulses in the same amplifier.

OCIS Codes: (060.2320) Fiber optics amplifiers and oscillators; (140.3510) Lasers, fiber

1. Introduction

Fiber laser sources are capable of generating high power, efficient, and stable pulses in various wavelength ranges. Yb-doped fibers have produced very high average and peak-power pulses with very high optical efficiencies [1,2]. Er- and Er:Yb-doped fibers operate in the "eyesafe" region and may leverage some "telecom" component technology at low power levels. However, Er-based fiber technologies have not advanced to the power levels, pulse energies, or efficiencies demonstrated in Yb-doped fibers with good beam quality [3,4]. More recently, Tm-doped silica fiber lasers and amplifiers operating in the 2-micron spectral region pumped at 795nm have shown very high efficiencies with near-diffraction-limited output, surpassing that of Er- or Er:Yb-doped fibers and approaching that of Yb-doped fiber systems [5,6]. This high power, high efficiency operation and emission in the "eyesafe" wavelength range has made Tm-doped fiber amplification very promising for a variety of applications.

In this paper, we discuss our high average power, near-diffraction-limited, pulsed Tm-doped fiber amplifier (TDFA) system which produces >20W of average output power at 1.995μm with 20ns pulses and 100kHz repetition rate. This system is also capable of variable repetition rate operation, resulting in high average power output with high pulse energy and peak-power pulses.

2. Experimental Setup and Results

Our Tm-doped fiber amplifier system consists of a seed source amplified in a series of Tm-doped fibers. The seed is a gain-switched Tm-doped fiber laser (TDFL) which generates >300mW of average power and produces 10-30ns pulses at 1.995μm with variable repetition rates in the 10-500kHz range [7]. The seed pulses are pre-amplified in 25/250 non-polarization-maintaining large-mode-area (LMA) TDFA pumped with a 25W 795nm fiber-coupled diode. The output from the preamp is isolated and coupled into a 25/400 LMA TDFA pumped by 55W from a 795nm diode. A schematic of the TDFA system is shown in Fig. 1.

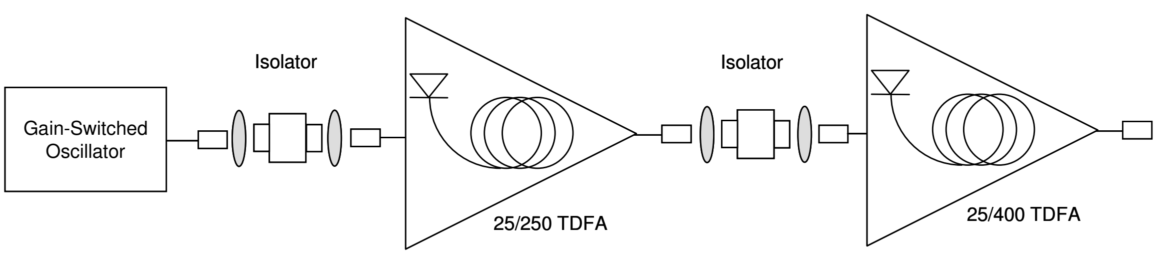
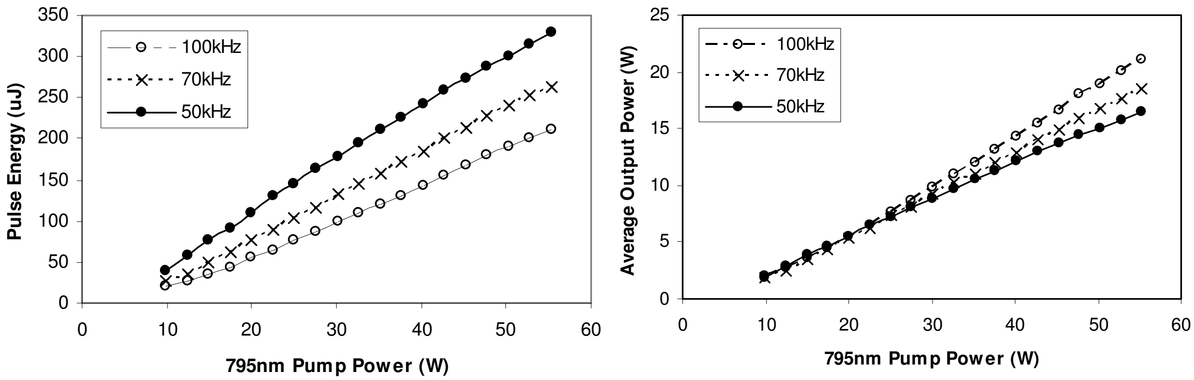


Fig. 1. Schematic of the dual-stage Tm-doped fiber amplifier system

The TDFL seed is randomly polarized, resulting in 50% transmission through the optical isolator. The 25/250 preamplifier operates with a 26% slope efficiency as a result of the relatively low seed energy which is coupled to the fiber core. The small-signal gain operation of this amplifier does, however, result in a gain of ~16dB from this preamplifier, resulting in >4W of output power. The output from the preamplifier is polarized with an extinction ratio of 5:1 as a result of the tight coiling of the fiber which induces birefringence in the core. An isolator at the output of the preamplifier acts to prevent feedback from the power amplifier. The performance of the power amplifier is shown in Fig. 2.



(a) (b)

Fig. 2. 25/400 power amplifier performance (a) pulse energy vs. pump power (b) average power vs. pump power

Transparency is reached in the 25/400 TDFA at a pump power of 10W, and the total gain in the power amplifier is 8dB, resulting in a total system gain of ~24dB. This gain was only limited by the available pump power. The maximum pulse energy generated from this system is 330μJ at 50kHz with 13ns pulses, corresponding to 25.4kW of peak-power. At 100kHz, 211μJ of pulse energy is generated with 20ns pulses, resulting in 10.5kW of peak-power. Beam quality was measured to be $M^2 < 1.2$.

The slope efficiency in the power amplifier is 43% at 100kHz and 32% at 50kHz, with respect to the launched pump power. These optical efficiencies may be improved by increasing the seed power the amplifier and operating in the saturated gain regime. In addition, operating at a slightly longer wavelength may further improve amplifier efficiency as the signal absorption decreases.

3. Conclusion

We have demonstrated high power, short pulse amplification in thulium-doped fibers pumped with 795nm diodes. To our knowledge, this is the highest pulse energy and peak-power generated from a pulsed thulium-doped fiber source. Future work will focus on increasing the output power by adding pump diodes to the system and increasing the seed power to improve conversion efficiency.

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4. References

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