Multistage 2 μm Polarization-Maintaining Single Clad Tm-Doped Fiber Amplifier

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ABSTRACT

2 μm high power and high performance amplifiers are needed for applications such as LIDAR, remote sensing, and WDM transmission systems. In this paper we report the experimental evaluation of the performance of multistage multiwatt optical amplifiers using a high performance PM single clad Tm-doped fiber. Our amplifier exhibits a large dynamic range (> 25 dB), a saturated output power > 2 W at 1909 nm, an optical bandwidth from 1875 to 2000 nm, a low noise figure (< 6 dB), a large OSNR (> 50 dB), and a PER > 20 dB.

Keywords: Optical Amplifier, Fiber Amplifier, Thulium, Polarization Maintaining, Infrared

1. Introduction and Overview

2 μm high power and high performance amplifiers are needed for applications such as LIDAR, remote sensing, and WDM transmission systems [1-4]. We have recently demonstrated that single clad Tm-doped amplifiers (TDFAs) can offer large bandwidth, high dynamic range, and multi-watt output power from 1.85 to 2.05 μm. [5-7]. More recently, we have presented the results of a miniature, high gain, low noise figure, broadband single stage PM amplifier using a newly developed single clad PM Tm doped fiber [8]. In this paper we report the experimental evaluation of the performance of a fully integrated, compact, multistage, multi-watt amplifier using the same PM single clad Tm-doped fiber.

Design optimization of the multistage amplifier is critical in order to offer a combination of performance under different operating conditions and in our presentation we will discuss the topologies and trade-offs that lead to our final design. Our tandem amplifier consists of a preamplifier stage followed by a booster stage, with both stages being pumped separately by an L-band pump at 1560 nm. In this paper, we report first experimental results and performance of the multistage packaged optical amplifier using this new fiber which is described in Table 1 below. Among other features, our amplifier exhibits a large dynamic range (> 25 dB), a saturated output power > 2 W at 1909 nm, an optical bandwidth from 1875 to 2000 nm, a low noise figure (< 6 dB), a large OSNR (> 50 dB/0.1 nm), and a PER > 20 dB.

Parameter	Value
Fiber ID	IXF-TDF-PM-4-125
Core Diameter, μm	4.5
Fiber Structure	Single Clad PANDA
Estimated Core Absorption at 790 nm, dB/m	134
Estimated Core Absorption at 1180 nm, dB/m	33.5
Peak Core Absorption at 1650 nm, dB/m	114
Birefringence	$> 1.5 \times 10^{-4}$
Numerical Aperture	0.25

Table 1. Parameters for newly developed iXblue PM Thulium-doped single clad fiber

2. Amplifier Package and Optical Schematic Diagram

Figure 1 is a photograph of the packaged multistage Tm-doped fiber optical amplifier. The dimensions of the packaged amplifier are 200 × 150 × 43 mm^3 and the mass is approximately 1000 g. The amplifier incorporates full electronic control circuits with a microprocessor for pump current and temperature stabilization and input and output power monitoring. External communications are via a USB interface. At maximum optical output power and 25 ˚C, the electrical power consumption of the packaged amplifier is 66 W.

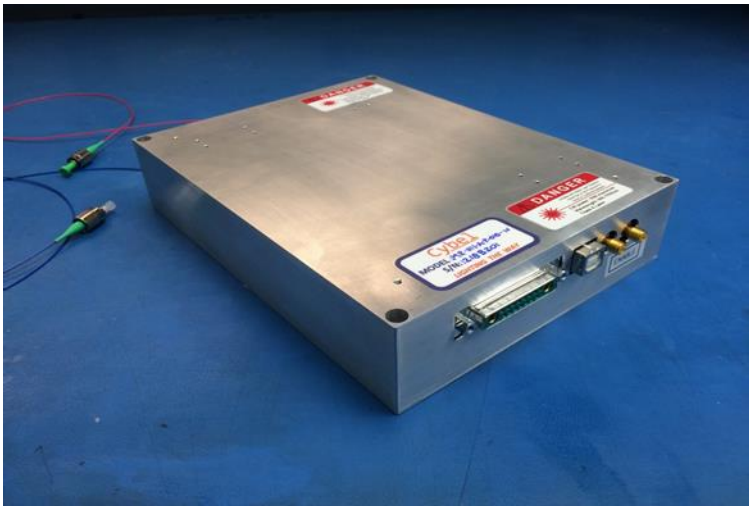

Figure 1. Photograph of the packaged and fully integrated multistage Tm-doped fiber amplifier.

Figure 2 is an optical schematic diagram of the multistage PM amplifier architecture. The input signal light at wavelengths from 1909—2004 nm passes through an input FC/APC connector, isolator I1, and wavelength division multiplexer WDM1 and is amplified in PM single clad Tm-doped fiber F1. The signal output from F1 is coupled through isolator I2 into the second amplifying stage F2, and the signal output of F2 passes through WDM2 and isolator I3 to the output FC/APC connector. Pump P1 is a multi-watt 1560 nm Er:Yb fiber laser, pumped itself by a 940 nm multimode semiconductor diode laser. As indicated in the schematic, the preamplifier stage F1 is co-pumped, while the power amplifier stage F2 is counter-pumped. Coupler C1 directs 20% of the 1560 nm pump light to preamplifier stage F1 and 80% to power amplifier stage F2.

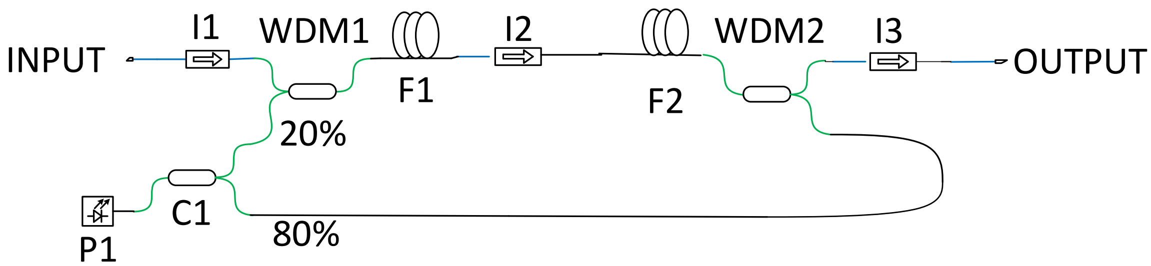

Figure 2. Optical Schematic Diagram of the Multi-Stage PM Tm-doped Fiber Amplifier.

3. Experimental Results

Figure 3 plots the measured output optical power vs. internal 940 nm semiconductor pump laser current at a signal wavelength of 1909 nm for input signal powers of -3, 0 , and +3 dBm. A very small variation in output power as a function of input signal power is observed and the measured slope is 0.40 W/A.

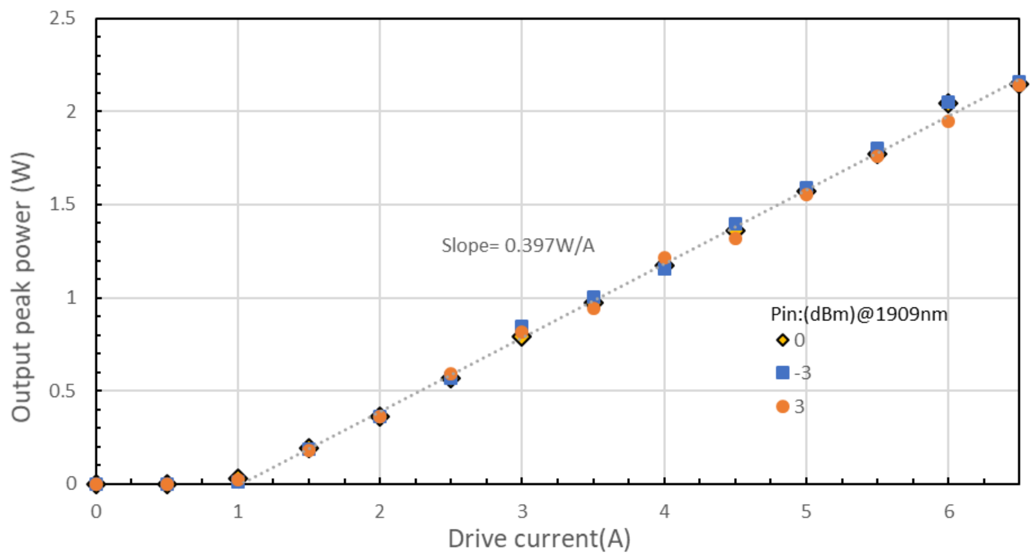

Figure 3. Measured Output Power at 1909 nm vs. Pump Laser Drive Current for 3 Values of Input Power

Figure 4 shows the measured output power stability at a drive current of 4 A and a mean output power of 1.22 W. The measured power variation is < 2 % p-p after a 30 minute warmup period, demonstrating the excellent long term stability of the packaged multistage PM fiber optical amplifier.

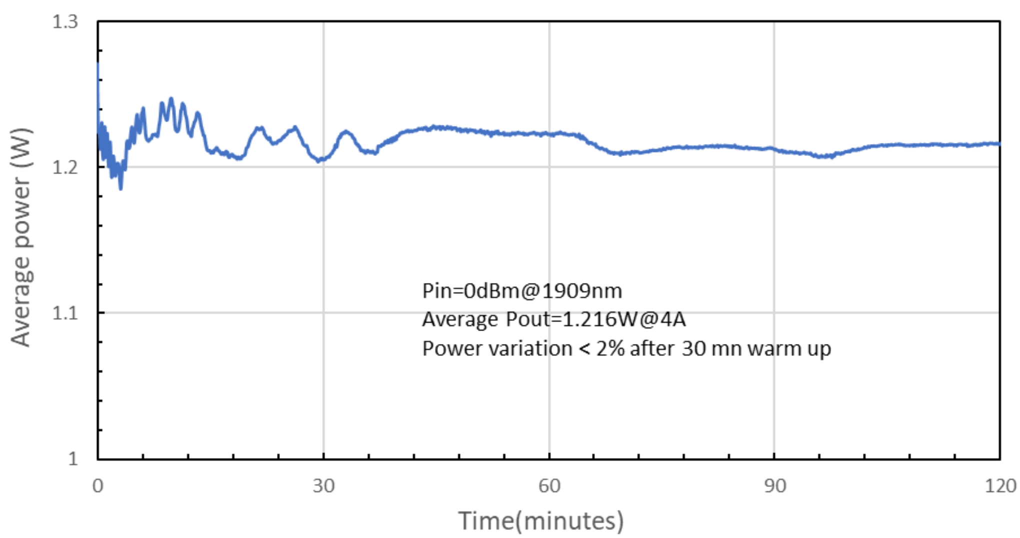

Figure 4. Measured Output Power Stability vs. Time at P_{out} = 1.22 W.

In Figure 5, we plot the measured output power spectra as a function of signal wavelength for 1909, 1951, and 2004 nm. The design of the amplifier presented here is optimized for 1909 and 1951 nm signal wavelengths. At the conference, we will present amplifier designs incorporating 1) a gain flattening filter and 2) modified first and second stage active fiber lengths that optimize performance for the full span of signal wavelengths studied.

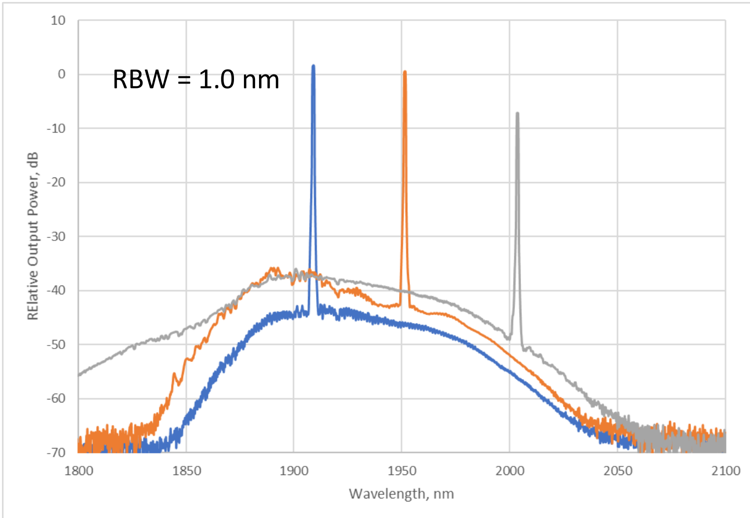

Figure 5. Measured Output Spectra of PM TDFA for Input Signal Wavelengths of 1909, 1952, and 2004 nm.

Also at the conference, we will present topologies and designs that lead to more fully optimized amplifier performance as a function of signal input power, pump power, small signal gain, and small signal noise figure.

4. Acknowledgement

This work was funded by NASA SBIR Phase I Contract # 80NSSC19C0278.

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