1760 nm Multi-Watt Broadband PM Tm-doped Fiber Amplifier

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Abstract: We report the performance of a CW single-clad PM Tm-doped fiber amplifier optimized for the wavelength band from 1760 to 1960 nm. Output powers as high as 3 W and an OSNR > 55 dB/0.1 nm are achieved with our OEM packaged amplifier.

1. Introduction

Recent work in thulium-doped fiber amplifiers (TDFAs) demonstrates that these devices are capable of operation over a wide wavelength region spanning 1630–2000 nm [1–7]. While conventional TDFAs typically span 1850–2000 nm [5-7], extended wavelength TDFAs using custom research Ge/Tm co-doped silica fibers operate at wavelengths as low as 1630 nm [1-4]. TDFAs which readily access the 1730–1800 nm region are of particular interest because of rich molecular absorptions near 1730 and 1760 nm that are quite important for biophotonics applications [8]. In this paper we propose and demonstrate a high-performance broadband PM TDFA operating at 1760–1960 nm that uses standard commercially available Tm-doped fibers, has a fiber coupled output power as high as 3 W CW, and is constructed in a compact (200x150x43 mm^3) OEM package designed for immediate integration into existing laboratory setups.

2. TDFA Architecture and Experimental and Simulated Performance

Figure 1 shows the configuration of the 1760 nm PM TDFA. This amplifier consists of a preamplifier stage followed by a booster stage. A 9-W 1567 nm pump is split by a 75/25 passive coupler C1 to counter-pump (25%) the preamplifier stage and co-pump (75%) the booster stage via high power fiber wavelength division multiplexers WDM1 and WDM2. Both amplifier stages use the same standard commercial 5 µm core PM TDF (iXblue IXF-TDF-PM-5-125). The gain fibers F1 and F2 are both 1 m long. In the current experiments, an interstage isolator I2 was used. This will be replaced in the future by an interstage filter composed of a circulator (CIR1) and a narrow-band fiber Bragg grating (FBG1) reflector. Both the input and output of the amplifier are protected from reflections by the isolators I1 and I3, respectively.

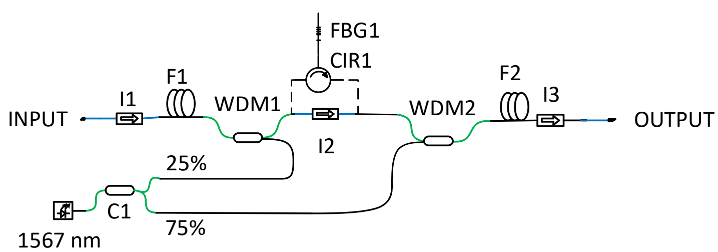

Fig. 1. Optical architecture of the two-stage PM 1760 nm TDFA.

Figure 2 shows the experimental and simulation results obtained with the PM TDFA. Up to 2.9W of output signal power was obtained with 4.75 mW of input power and 9 W of pump power, resulting in an external amplifier gain of 27.9 dB and optical-to-optical slope efficiency $\eta = 33.5\%$. The simulated signal output power is 8% higher than the experimentally measured power.

The experimentally measured output spectrum, displayed in red in Fig. 2(b), shows more than 55 dB/0.1 nm of optical signal-to-noise ratio (OSNR) and less than 2% of the total power emitted in the amplified spontaneous emission (ASE). Due to the co-pumped architecture of the booster stage amplifier, about 240 mW of residual pump power is present at the amplifier output. The simulated spectrum shows a good agreement with the measurements, with the exception of the long-wave regime (1850–1950 nm) where it predicts higher ASE levels. This discrepancy is caused by the wavelength response function of the fused fiber 1567/1760 nm WDM which was not included in the simulations.

The architecture of the PM TDFA allows for a broad-band operation of the amplifier, as shown by the simulation results displayed in Fig. 3(a). The output power above 3 W can be achieved for the signal wavelengths between 1760 and 1960 nm, while the noise figure remains below 9.5 dB and decreases towards the higher operation wavelengths.

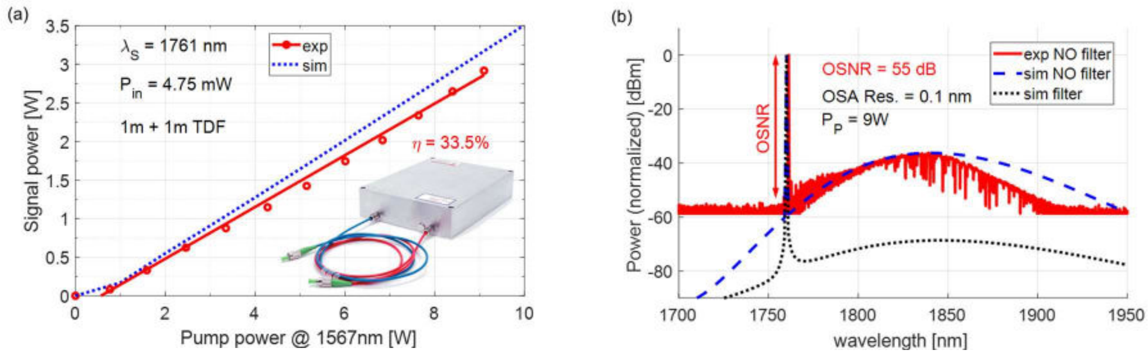

Fig. 2. (a) Output power of the TDFA vs 1567 nm pump power for 4.75 mW of CW input signal at 1761 nm. Inset shows the OEM package. (b) Output spectra of the TDFA: experimentally measured (red) and simulated (blue) spectra with inter-stage isolator are compared with the simulated spectrum with an interstage filter (black).

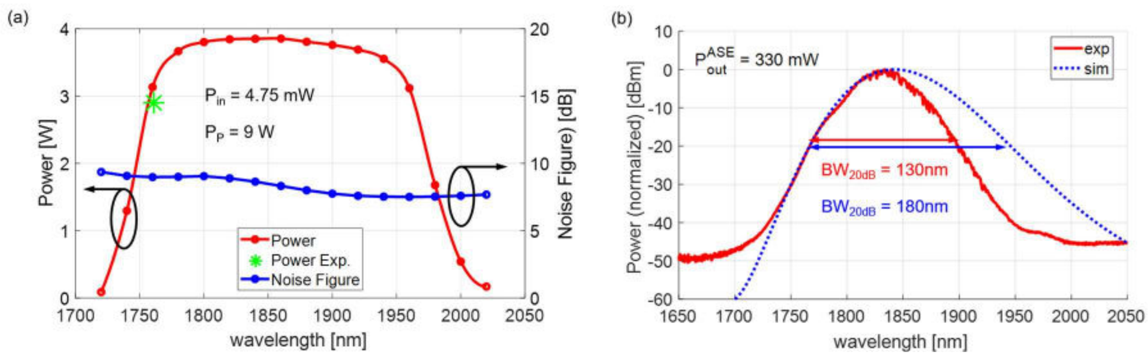

Fig. 3. (a) Simulated output powers (red, left axis) and noise figures (blue, right axis) of the dual-stage TDFA as a function of input signal wavelength. Experimentally measured power is marked with a green asterisk (b) Spectrum of the dual-stage TDFA operated as an ASE source.

The TDFA can also be operated as a broad-band ASE source, as illustrated in Fig. 3(b). Up to 330 mW of output power has been experimentally measured with the pump power of 1.5 W. The 20-dB bandwidth of the ASE source was measured to be 130 nm spanning between 1770 and 1900 nm. Similar ASE power output was obtained in simulations with 1 W of pump power. Similar to the previous results, the simulations predict the ASE bandwidth that extends 50 nm wider towards the long wavelengths.

In conclusion we have proposed and demonstrated a broadband PM TDFA capable of 3 W CW fiber coupled output power over a wide wavelength range of 1760–1960 nm. The OEM packaged amplifier is designed for rapid integration into existing laboratory setups and photonic equipment. Immediate biophotonics applications include selective imaging of lipids and proteins by excitation of CH_2 in the 1730–1760 nm optical window [8].

3. References

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