Tunable 30W all-fiber laser emitting around 1850 nm

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Abstract*:* We have demonstrated a tunable polarization maintaining thulium-doped fiber laser spanning the 1830nm-1880nm range with a fiber-coupled output power as high as 30W CW. The high-power booster stage is made using double clad fibers pumped with 793nm laser diodes.

In recent years, thulium-doped fiber amplifiers have become increasingly popular due to their broad emission band ranging from 1600 nm to 2100 nm. Conventional amplifiers exploit emission between 1900 nm and 2000 nm and typically rely on pumping fibers in the cladding using high-power 793 nm laser diodes [1-3]. Research covering the range of 1800 nm to 1900 nm is less explored, although the region between 1830 nm and 1880 nm offers opportunities for quantum computing/simulation applications. For example, nonlinear frequency generation with a 1550 nm laser can result in high-power sources around 840 nm. Several studies have been already been published; for instance, Shen et al. (2006) demonstrated a tunable laser between 1750 nm and 1900 nm with a maximum continuous-wave (CW) output power of 8 W at 1850 nm [4]. However, most of these lasers are either power-limited or realized using free-space optics. Few works on an all-fiber system have been reported, apart from the notable work of Meleshkevich et al. (2005), who demonstrated single-frequency operation up to 10 W in an all-fiber configuration [5]. The majority of these results are achieved using a core-pumping configuration with a single-mode laser emitting in the 1550nm-1580 nm window and limited in power. This work presents a polarized, fully fibered tunable laser source operating between 1830 nm and 1880 nm, with output power up to 30W. The high-power amplification stage is realized using double-clad fibers pumped with 793 nm laser diodes.

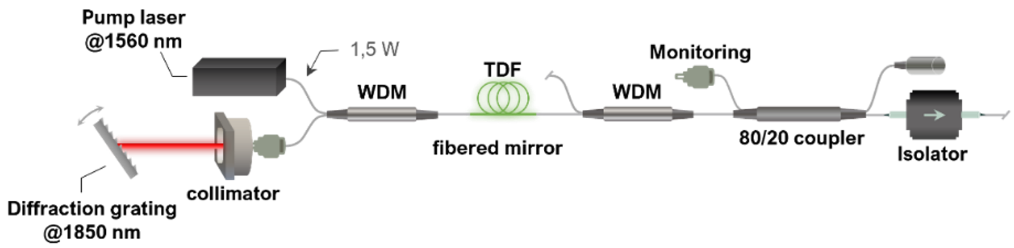

Figure 1 : Schematic of the tunable laser. WDM: Wavelength Division Multiplexer; TDF: Thulium-doped fiber.

To study the amplification process in Thulium doped fibers below 1900 nm, a tunable fiber laser was developed (see Fig. 1). The principle involves a linear cavity with grating tuning using the Littrow configuration and core pumping to enhance operation at short wavelengths. The Thulium-doped fiber is a polarization-maintaining active fiber. At the output, a minimum power of 80 mW is achieved over the wavelength range of 1800 nm-1900 nm. The spectra at this power level, depicted in Figure 2(a), exhibit an optical signal-to-noise ratio (OSNR) of less than -75 dB, limited by the sensitivity of the optical spectrum analyzer.

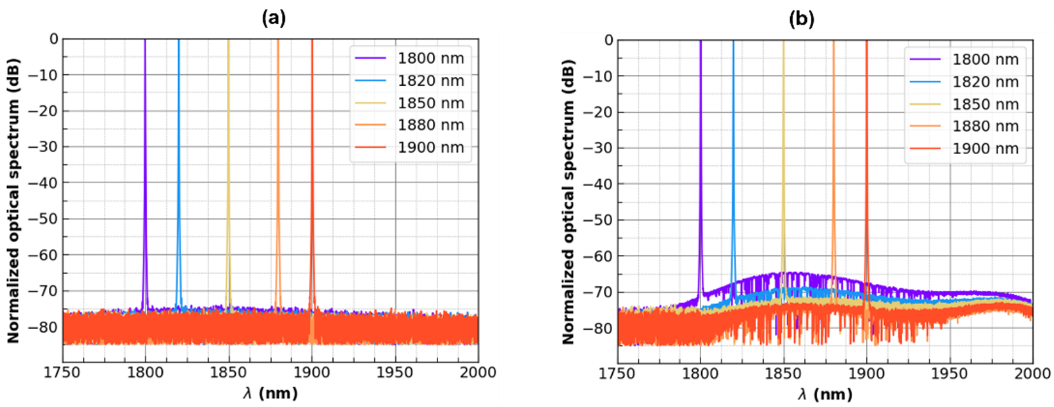

Figure 2 : Normalized spectra obtained: a) At the tunable laser output (laser power = 80 mW) b) At the preamplifier output with a laser power of 1W (0.1 nm optical resolution bandwidth).

Following this, the laser output power has been set to 80 mW for all wavelengths, and two amplification stages has been developed (figure 3). The first amplification stage utilizes the same Thulium-doped fiber as the seeder, pumped in a counter-propagating configuration by a laser (2.4 W at 1560 nm). The output power varies from 0.98 W at 1800 nm to 1.1 W at 1850 nm, with a conversion efficiency after isolator exceeding 45%. Optical spectra were measured with a laser power of 1 W and are depicted in Figure 2(b). The OSNR is above 70 dB from 1830 nm to 1900 nm and approaches 65 dB at 1800 nm.

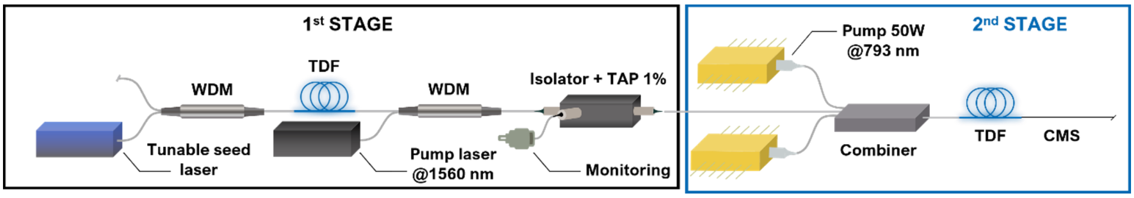

Figure 3 : Schematic of the two all-fibered amplification stages. The first stage is pumped by a single mode laser emitting at 1560 nm while the second stage is pumped by two multimode diodes at 793 nm. CMS: Cladding Mode Stripper.

For the final stage, the active fiber used is double-clad, allowing pumping by two multimode diodes emitting up to 50 W at 793 nm. A mode stripper (CMS) is employed to remove pump power that has not been absorbed.

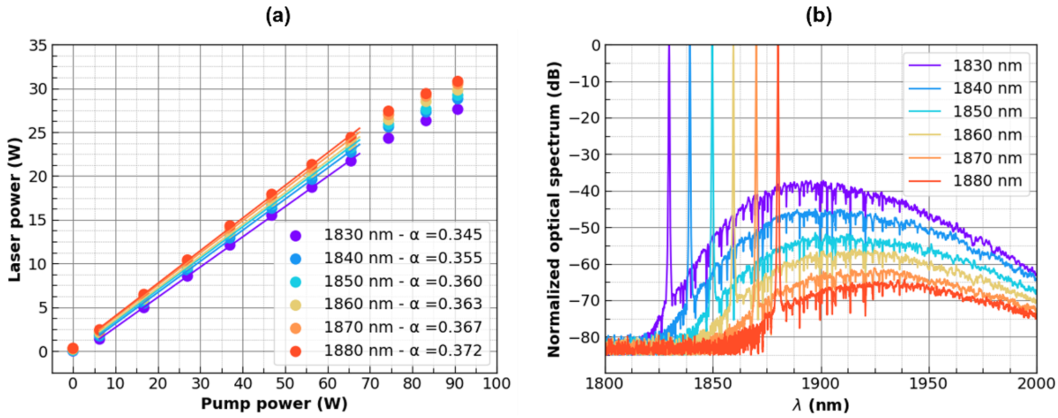

Figure 4 : Final amplifier stage output power for wavelengths between 1830 nm and 1880 nm versus total pump power, (b) Normalized optical spectra obtained at each wavelength of Fig. 6(a) at maximum output power (0.1 nm optical resolution bandwidth).

The output power of the preamplifier was set to 1 W for all wavelengths. Figure 4(a) displays the laser system's conversion efficiency, which varies from 34% at 1830 nm to 37% at 1880 nm, with power ranging from 27.6 W to 30.8 W. When the pump power exceeds 60 W, the laser power no longer increases linearly. This is attributed to the spectral shift of the diodes due to increased current passing through them. The optical spectra at maximum fiber output power are presented in Figure 4(b). The OSNR increases rapidly from 39 dB at 1830 nm to 67 dB at 1880 nm, with integrated amplified spontaneous emission over total power of 3% and 0.007%, respectively. It should be noted that the amplifier was not characterized for shorter or longer wavelengths due to the specifications of passive components. To verify the amplifier's robustness, a long-term endurance test at 1850 nm, was conducted over a period exceeding 900 hours and shows that the laser power, initially at 31 W, gradually decreases to a value of 29 W (about a 4% variation).

Following the future development of a low-frequency and intensity noise extended cavity laser, the system will be used for single-frequency emission, enabling the study of noise transfer mechanisms and the stimulated Brillouin scattering (SBS) threshold.

In conclusion, we have developed a fully fibered tunable laser amplifier operating between 1830 nm and 1880 nm, featuring a linearly polarized beam and output power ranging from 29 W to 31 W. This achievement was realized using a cladding-pumping configuration with multimode diodes emitting at 793 nm. The OSNR is close to 40 dB at 1830 nm (65dB) at 1880 nm, ensuring robustness of the system.

References

[1] X. Wang et al, “All-fiber high-average power nanosecond-pulsed master-oscillator power amplifier at 2m with mJ-level pulse energy,” Applied Optics, **55**, 1941-1945, (2016).
[2] C. Kieleck et al, “6.5 W ZnGeP2 OPO directly pumped by a Q-switched Tm3+-doped single-oscillator fiber laser,” Opt. Lett., **40**, 1101-1104, (2015).
[3] T. Ehrenreich, R. Leveille, I. Majid, K. Tankala, G. Rines, and P. Moulton, “1-kW, all-glass Tm: fiber laser,” Proc. SPIE 7580, 758016 (2010).
[4] M. Meleshkevich et al., "10 W single-mode single frequency Tm-doped fiber amplifiers optimized for 1800–2020-nm band," Proc. SPIE 5709, Fiber Lasers II: Technology, Systems, and Applications, (2005).
[5] W. A. Clarkson, N. P. Barnes, P. W. Turner, J. Nilsson, and D. C. Hanna, “High-power cladding-pumped Tm-doped silica fiber laser with wavelength tuning from 1860 to 2090 nm,” Opt. Lett., **27**, 1989-199, (2002).