

Multi-Watt Broadband Wavelength Tunable Polarization Maintaining Tm-doped Fiber Laser Module

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1. Abstract We report the design, optical architecture, and performance of a multi-watt tunable polarization-maintaining Tm-doped fiber laser that can be tuned from 1890—2050 nm. The compact OEM laser exhibits peak fiber coupled output powers of > 3.5 W CW and a linewidth of < 0.05 nm. Data as a function of output wavelength are presented for the output spectrum, output power, OSNR, and long term power stability.

2. Introduction Tunable narrow linewidth single frequency lasers in the 2000 nm region are important as sources for mid-IR generation, LIDAR, DWDM, and coherent systems, and infrared spectroscopy and gas sensing applications [1—4]. Initial demonstrations of tunable Tm-doped fiber lasers (TDFLs) showed output powers of 1 mW and a tuning range of over 300 nm (1650—2000 nm) [5]. Subsequent reports exhibited tuning ranges well over 120 nm and output powers in excess of 300 W using a seed laser-MOPA configuration [6—9]. All of these tunable sources were built using standard or non-polarization-maintaining (non-PM) single mode fibers. PM TDFLs with good performance have been exhibited [10] but these sources operate only at a fixed output wavelength.

In this paper we report the design and experimental performance of a tunable OEM PM Watt-level TDFL. Our device is built in a compact self-contained package that is suitable for integration into system applications or laboratory experimental setups. We employ a novel uncooled 940 nm semiconductor laser pumping arrangement in our TDFL source. We study the output power, output spectrum, and optical signal-to-noise ratio (OSNR) of the tunable laser source over a wide tuning range of 1890—2050 nm. We also present detailed measurements of insertion loss as a function of wavelength for a fiber coupled 2000 nm band acousto-optic (A/O) modulator.

3. Optical Architecture and Laser Packaging

Figure 1 shows the optical schematic diagram of the tunable PM Tm-doped fiber laser.

F1, the PM active Tm-doped fiber in the laser, is described in detail in Ref. [11]. A 6 meter long ring laser cavity is formed using all polarization maintaining components F1, isolators I1 and I2, wavelength division multiplexer WDM1, 50/50 coupler C2, and tunable bandpass filter TBPF1.

An Er-Yb fiber laser pump source P1 operating at 1567 nm is split by coupler C1 and 20% of this laser output is coupled into the ring laser via 1567/2050 nm WDM1. The Er-Yb laser consists of a length of Er-Yb doped fiber and two 1567 nm fiber gratings which are pumped by an uncooled 940 nm multimode semiconductor laser source.

The signal output from the ring laser cavity is subsequently coupled through the 50% port of C2 to the input of a PM Tm-doped power amplifier F2, which is pumped through WDM2 by the 80% output of the Er-Yb 1567 nm pump laser source. 1/99 Coupler C3 provides a monitor output for the ring laser signal. The amplified output of F2 then passes through isolator I3 to the FC/APC output connector of the packaged laser.

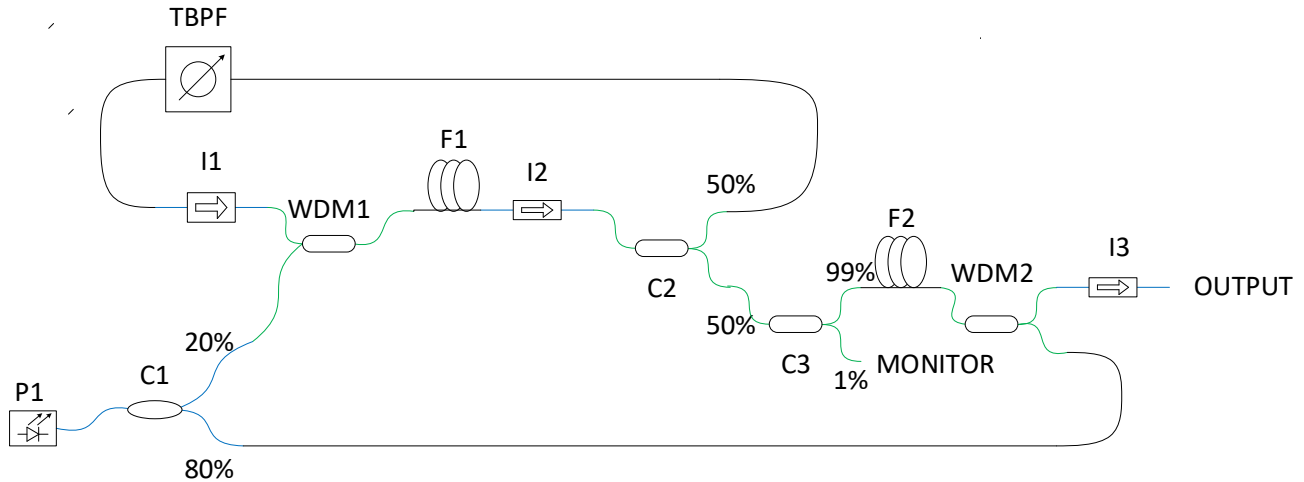


Figure 1. Optical Schematic Diagram of the Tunable Tm-doped Fiber Laser

Figure 2 is a photograph of the OEM packaged PM tunable TDFL. The OEM laser incorporates full pump control, has dimensions of $200 \times 150 \times 43 \text{ mm}^3$, a mass of 600 g, and is powered by 18-30 VDC. Electrical power consumption at full optical output power is 66 W. Communication is with USB and RS232 interfaces. The active PM Tm-doped fiber in the laser is described in detail in Ref. [11].



Figure 2. Packaged Watt-level Tunable PM TDFL ($200 \times 150 \times 43 \text{ mm}^3$)

4. Experimental Results Figure 3 shows the output spectra of the amplified laser output at wavelengths of 1890–2050 nm. The amplified output linewidth is measured with an optical spectrum analyzer to be less than 0.05 nm (4 GHz). At each of these wavelengths the PM output power of the TDFL is over 1.5 W CW.

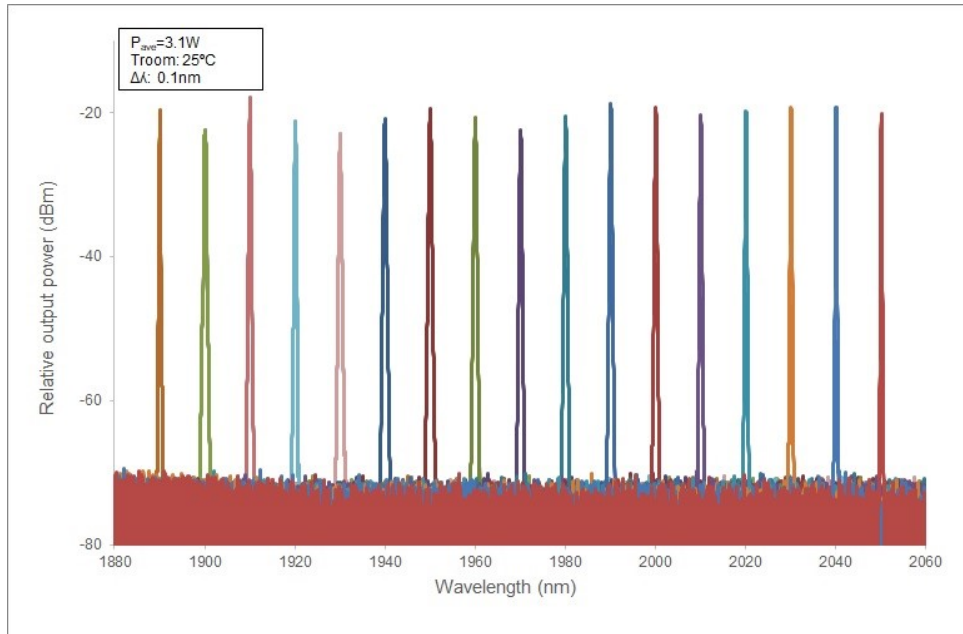


Figure 3. Experimental Spectra of the Amplified Laser Output

Figure 4 plots the measured output power of the tunable amplified ring laser source as a function of wavelength for three different average output power levels (3.1 W, 2.2 W, and 1.25 W). The peak output power at maximum drive current is clearly greater than 3.5 W CW.

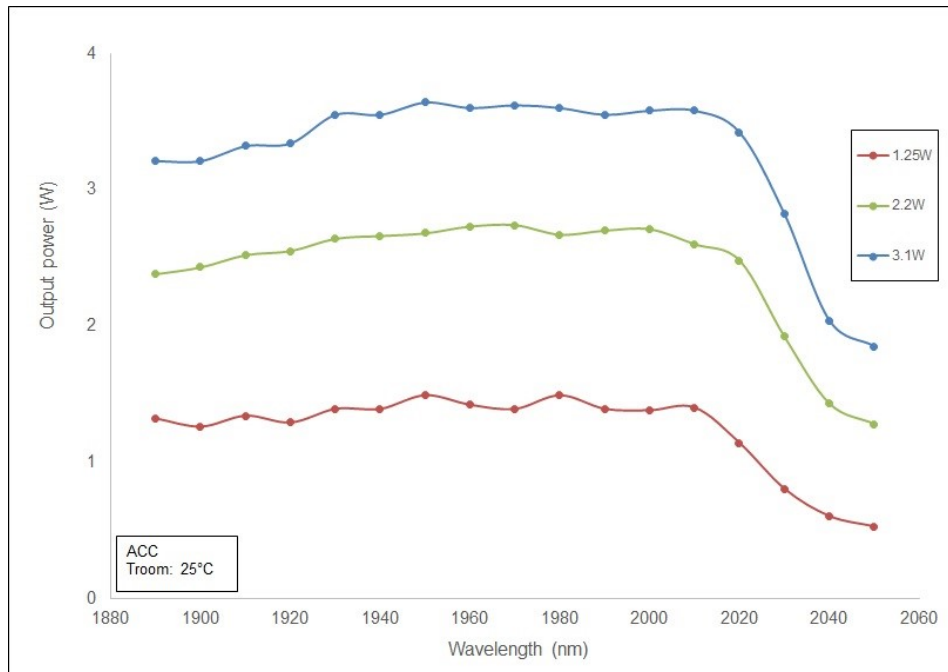


Figure 4. Output Power vs. Wavelength for Three Average Output Power Values

The measured optical signal to noise ratio (OSNR) for the tunable fiber laser source as a function of output wavelength was found to be $> 48 \text{ dB}/0.1 \text{ nm}$ for 1890—2050 nm as shown in Figure 5.

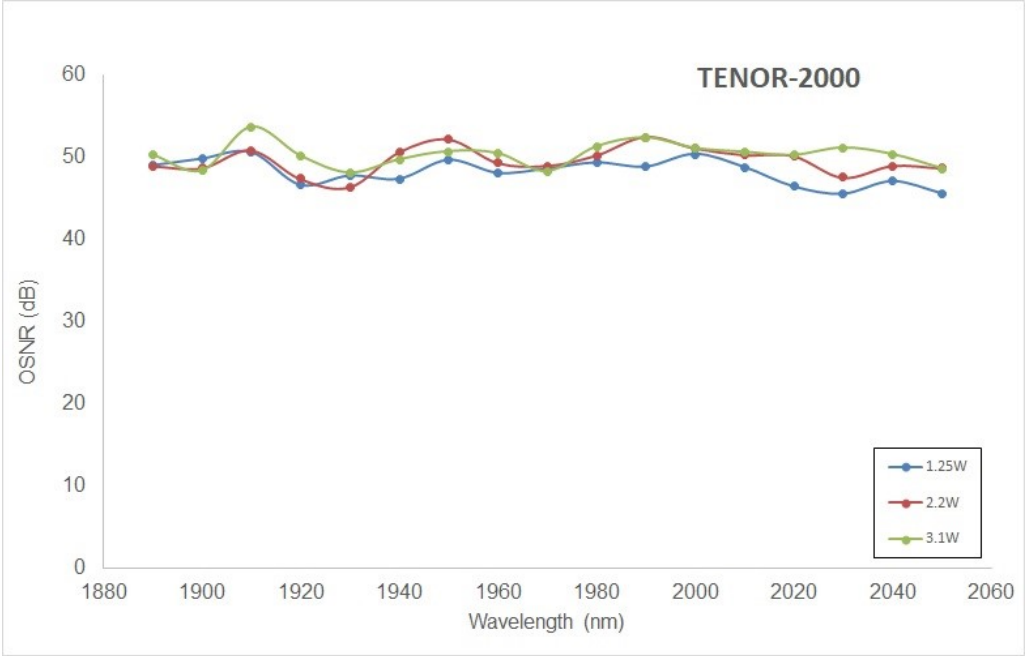


Figure 5. Measured OSNR/0.1 nm as a Function of Laser Wavelength

Figure 6 illustrates the measured output power stability for the packaged ring laser source at output powers of approximately 1 W CW. As shown in the graph, after a 30 minute warmup period, the output power stability was $< \pm 4\%$ p-p.

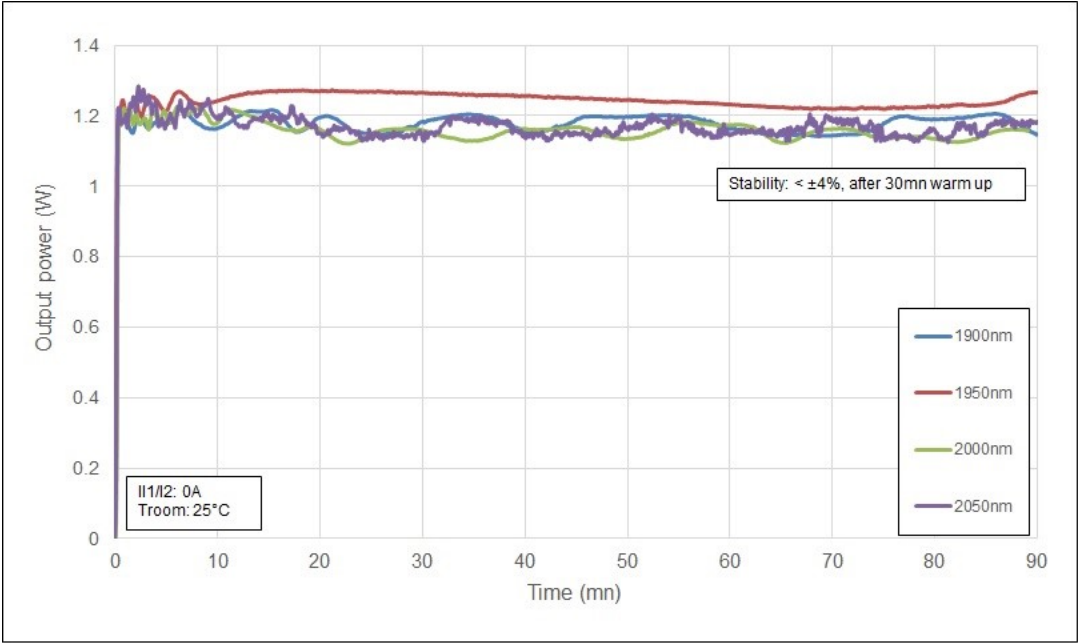


Figure 6. Long Term Stability of Tunable Fiber Laser Output Power

5. Loss vs. Wavelength Measurements for a 2000 nm Band A/O Modulator As an example of the measurements possible with the novel tunable laser source, in Figure 7 we plot the experimental optical insertion loss vs. wavelength for a representative polarization maintaining 2000 nm band fiber coupled A/O modulator. In this plot the measured data are represented by points and the dashed line is a parabolic fit to the data. For these measurements we scanned the TENOR wavelength in increments of 2.5 nm from 1890 nm to 2050 nm. The input power to the fiber coupled A/O modulator was set at 100 mW, and the modulator was operated at an amplitude modulation frequency of 1 MHz with a pulse length of 500 ns and a corresponding duty cycle of 50%. As Figure 7 illustrates, the measured insertion loss with wavelength varies from a minimum of 10.7 dB to a maximum of 11.6 dB over the full wavelength range. The evident structure on the data around the smooth fit is under investigation in the laboratory.

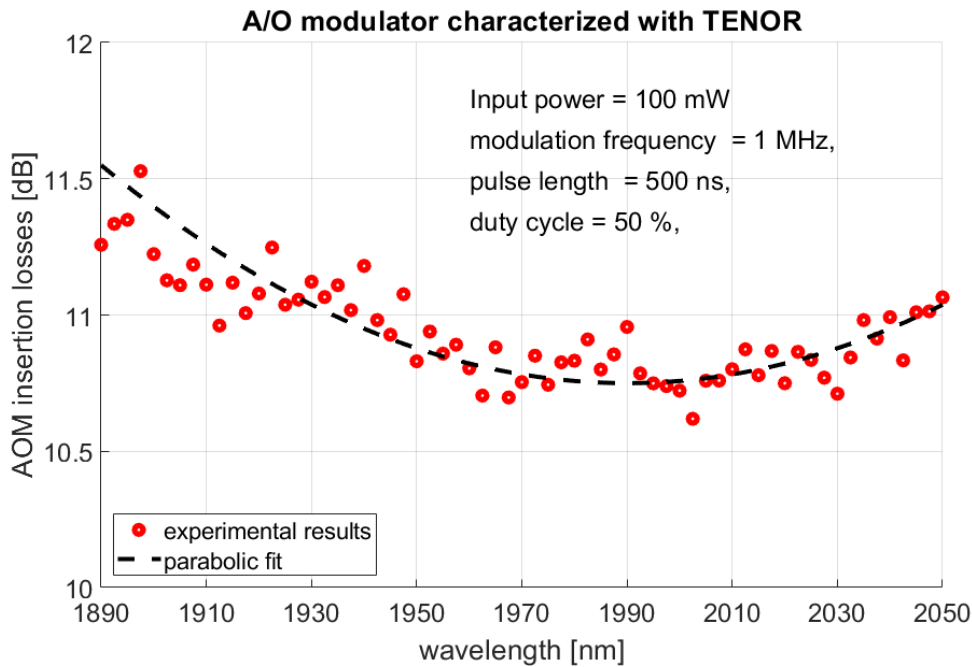


Figure 7. Loss vs. Wavelength for a Representative Fiber Coupled A/O Modulator using the TENOR Source.

6. Summary and Conclusions We have designed and experimentally demonstrated a tunable polarization-maintaining Tm-doped optically amplified fiber ring laser in a compact OEM package suitable for integration into manufacturing or laboratory applications. The OEM laser has a tuning range of 1890—2050 nm, an experimentally measured linewidth of < 0.05 nm (< 4 GHz), and peak fiber coupled output powers of > 3.5 W CW. Applications include sources for mid-IR generation, LIDAR, DWDM, and coherent systems, and infrared spectroscopy and gas sensing applications.

6. References

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