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Simulation Study on Output Power Characteristics of Tunable Thulium-Doped Fiber Ring Lasers

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1. INTRODUCTION

Tunable thulium-doped fiber lasers become a research focus due to high output power and wide wavelength tuning range. Different theoretical models have been investigated in the previous works to analyze performance of tunable thulium-doped fiber lasers but none of them has considered all the cavity parameters. In this work, we use a comprehensive theoretical model to analyze the output power characteristics of a tunable thulium-doped fiber ring laser as a function of the cavity parameters including active fiber length, output coupling ratio and the total intracavity loss.

2. LASER MODEL

Our theoretical model is developed based on the atomic rate equations and power propagation equations. The steady-state rate equation can be written as

$$\frac{dN_1(z)}{dt} = -\frac{dN_2(z)}{dt} = -W_a(z)N_1(z) + [W_e(z) + \frac{1}{\tau}]N_2(z) = 0 \quad (1)$$

The power propagation equations for the forward- and backward-propagated can be described by

$$\frac{dP^{\pm}(z,v)}{dt} = \pm 2hv\Delta v\Gamma(v)\sigma_e(v)N_2(z) \pm [\sigma_e(v)N_2(z) - \sigma_a(v)N_1(z)]\Gamma(v)P^{\pm}(z,v) \quad (2)$$

3. SIMULATION RESULTS

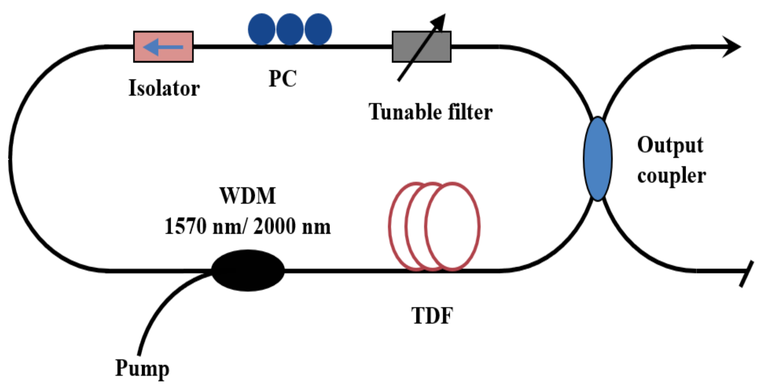

Fig. 1. Schematic diagram of the tunable TDFRL: Pump laser at 1565 nm; PC, polarization controller; WDM, wavelength division multiplexer; TDF, thulium-doped fiber.

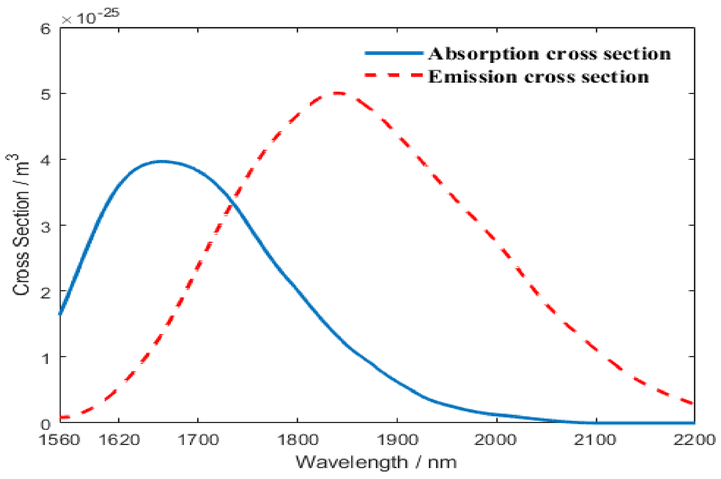

Fig. 2. Absorption and emission cross-sections of thulium-doped fiber.

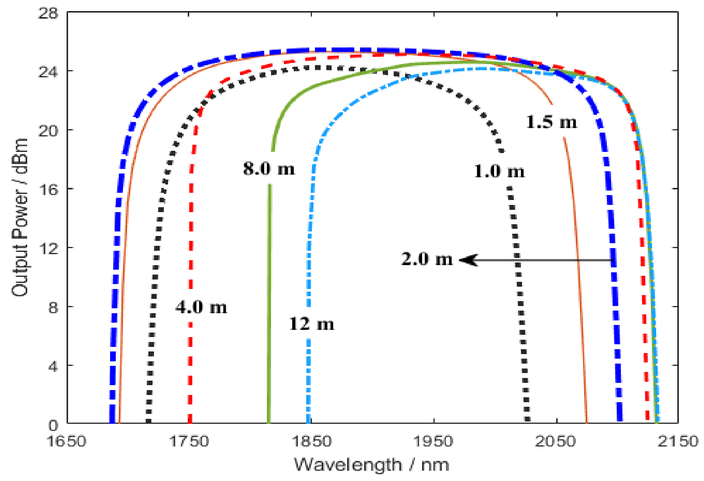

Fig. 3. Output power versus wavelength for different TDF lengths. η_{oc} = 0.5, ε_{total} = 9 dB.

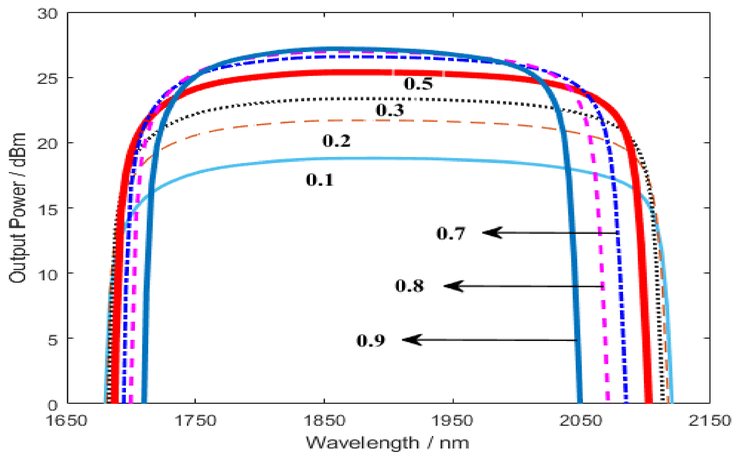

Fig. 4. Output power versus wavelength for different output coupling ratios. L = 2.0 m, ε_{total} = 9 dB.

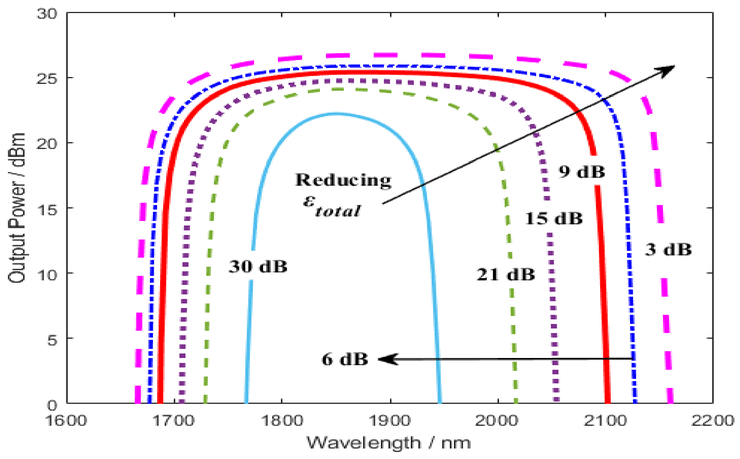

Fig. 5. Output power versus wavelength for different total intracavity losses. L = 2.0 m, η_{oc} = 0.5.

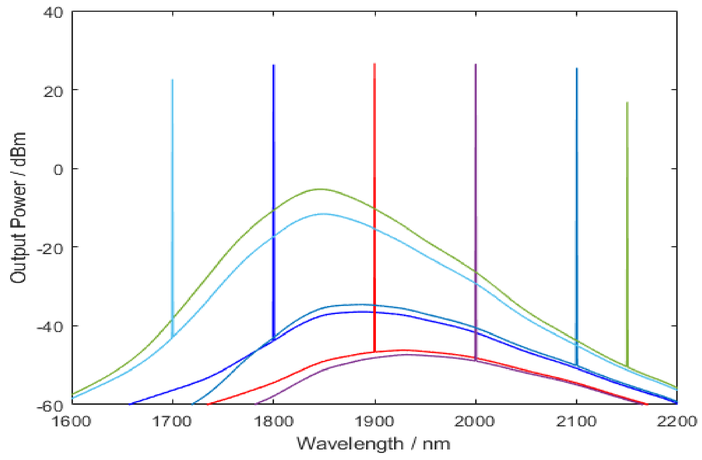

Fig. 6. Laser output spectra. L = 2.0 m, η_{oc} = 0.5 and ε_{total} = 3 dB.

4. CONCLUSION

In this work, basing on absorption and emission cross-sections as well as a pump laser at 1565 nm with the output power of 1.0 W, we simulate the output power of a tunable thulium-doped fiber ring laser for different cavity parameters. Numerical results have indicated that optimization of the active fiber length and the output coupling ratio as well as minimization of the intracavity loss are extremely important for achieving good performance in a tunable thulium-doped fiber ring laser. This model is helpful for the design and optimization of thulium-doped fiber lasers.