Thulium-doped fiber random laser using random fiber grating for random feedback

Decai Zhu[1,2], Yaozong Hu[1,2], and Xinyong Dong[1,2*]

[1]*School of Information Engineering, Guangdong University of Technology, Guangzhou, 510006, China*
[2]*Guangdong Provincial Key Laboratory of Information Photonics Technology, Guangzhou, 510006, China*
**E-mail: dongxy@gdut.edu.cn*

***Abstract*—We report on a Thulium-doped fiber random laser which uses a random fiber grating for distributed random feedback. The random fiber grating fabricated by using a femtosecond laser provides enhanced Rayleigh scattering in random feedback fiber so the total fiber length of the Thulium-doped fiber random laser is greatly reduced. A high-reflectivity fiber Bragg grating was used to form a half-open cavity structure. Random lasing at 1940 nm with optical signal-to-noise ratio up to 56 dB is achieved.**

Keywords: Random fiber laser, Thulium-doped fiber.

I. INTRODUCTION

Random fiber lasers have been widely studied due to their many advantages such as low coherence output and simple structure. They may have potential applications in remote sensing, imaging, and display [1-4]. Most random fiber lasers are based on distributed random feedback from Rayleigh backscattering in long single-mode fibers and gain from stimulated Raman or Brillouin scattering effect in the fiber [5-9]. However, due to the greatly increased propagation loss and low Rayleigh scattering in single-mode fibers at 2 μm than that at 1.0 or 1.5 μm. Random fiber lasers operated at 2 μm are difficult to achieve and rarely reported.

In this paper, we demonstrate a Thulium-doped fiber random laser by using a random fiber grating for distributed feedback and a Thulium-doped fiber for gain medium. Random laser output at the wavelength of 1940 nm with optical signal-to-noise ratio up to 56 dB is achieved.

II. EXPERIMENTAL SETUP

Experimental setup of the proposed Thulium-doped fiber random laser by using random fiber grating is shown in Fig. 1. The random fiber laser consists of a 1.5 m double-clad Tm^{3+}-doped silica fiber, a 793 nm pump laser diode (LD) with maximal output power of 5 W, a 793/2000 nm wavelength division multiplexers (WDM), a high-reflectivity fiber Bragg grating and random fiber grating were used to form a half-open cavity structure. As the pump power goes close to and above the threshold, as their net gain becomes larger than zero, peaks corresponding to resonances are observed in the output spectra.

The Thulium-doped fiber pumped by using a 793 nm pump laser diode provides gain of the random laser. The fiber Bragg grating is used to select the output wavelength of the Thulium-doped fiber random laser. The random fiber grating, which was inscribed on a normal silica fiber by using a femtosecond laser, contains over 6000 refractive-index-modulated spots randomly distributed along a 10 cm long single-mode fiber, providing distributed random feedback for the Thulium-doped fiber random laser. The output laser spectrum and optical power were measured by using an optical spectrum analyzer (OSA, AQ6376) with wavelength resolution of 0.1 nm and an optical power meter, respectively.

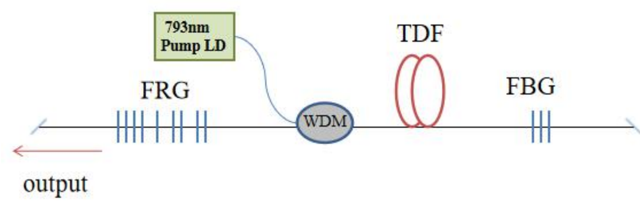

Fig. 1. Experimental setup of the Thulium-doped random fiber laser.

III. RESULTS AND DISCUSSION

The evolution of the laser output spectrum with pump power is observed. Resonance occurs once the gain exceeds the total loss, when pump laser is injected into the Thulium-doped fiber. It can be seen from Fig. 2 that random laser spectra vary with the pump power. The lasing peak with optical signal-to-noise ratio of 56 dB at 1940 nm .

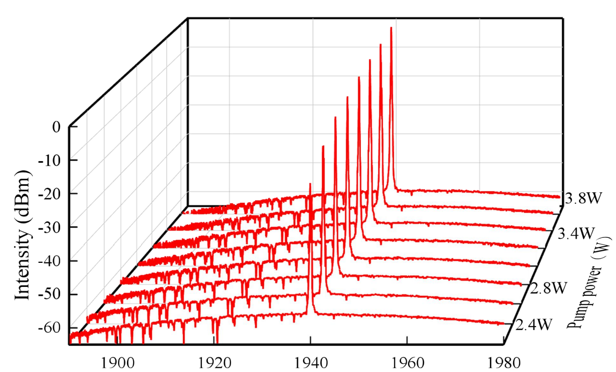

Fig. 2. Output spectra of the Thulium-doped fiber random laser.

Fig. 3 shows laser output power as a function of the injected pump power. The threshold pump power was 2.32 W. Above the threshold, the output power increased linearly with the pump power. The maximum laser output power was 58 mW achieved at pump power of 3.8 W, and the optical slope efficiency was ~4%.

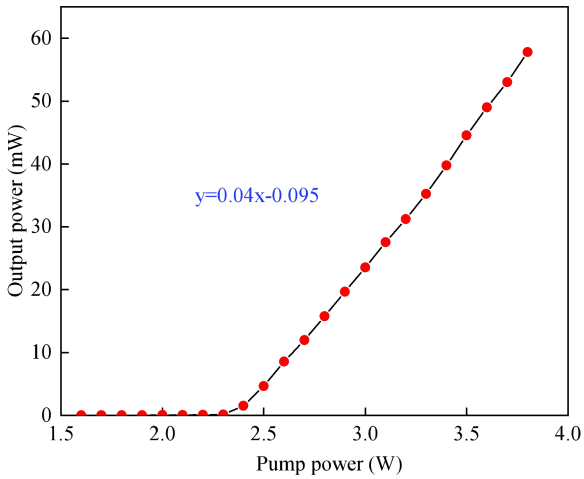

Fig. 3. Laser output power as a function of pump power.

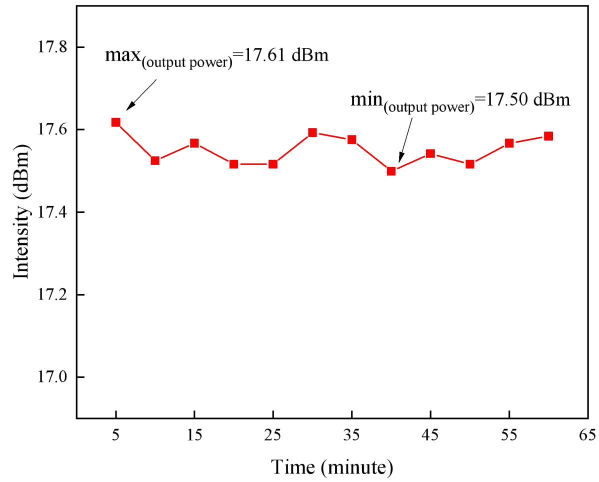

Fig.5. Laser output power fluctuation measured within 1 hour when pump power is 3.8W.

To test output stability of the random fiber laser, laser spectrum and output power were measured twelve times in 60 min at an interval of 5 min when the pump power was 3.8 W. The measured laser output spectra were shown in Fig. 4. Wavelength shift of the random fiber laser is less than 0.1 nm, which equals to the wavelength resolution of the optical spectrum analyzer, indicating that wavelength stability of Thulium-doped fiber random laser is very good. That may be attributed to the good wavelength selectivity of the high reflectivity fiber Bragg grating.

Fig. 5 shows the measured laser output power fluctuation. It can be seen that the maximum laser output power is 17.61 dBm and the minimum is 17.5 dBm. The maximum fluctuation is only 0.11 dB. The good stability may be attributed to the stable random feedback of the random fiber grating.

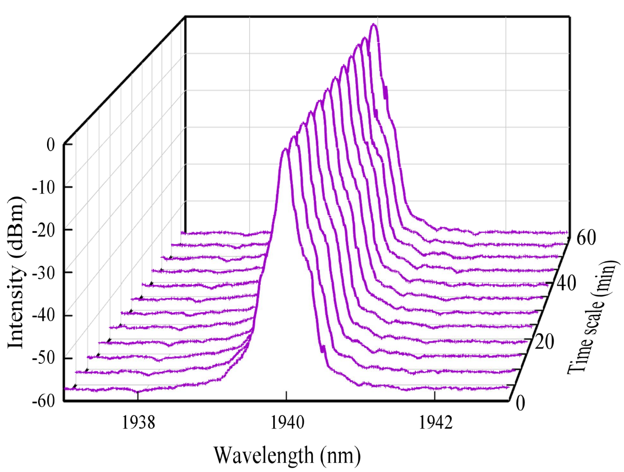

Fig. 4. Laser output spectra measured within 60 min when pump power is 3.8W.

IV. Conclusion

In conclusion, we have demonstrated a Thulium-doped fiber random laser by using a random fiber grating for random distributed feedback. Stable random lasing at 1940 nm with optical signal-to-noise ratio up to 56 dB was achieved. The maximum output random fiber laser reached 58 mW, and the slope efficiency was ~4%.

Acknowledgment

This work was supported by the National Natural Science Foundation of China with grant Nos of 61775204 and 11974083, and the Program for Guangdong Introducing Innovative and Enterpreneurial Teams (2019ZT08X340).

References

[1] M. Lawandy, R. M. Selschandran, A. S. Lgomes et al, "Laser action in strongly scattering media," Nature, 388, 346 (1994).

[2] H. E. Türeci, L. Ge, S. Rotter, A. D. Stone, "Strong interactions in multimode random lasers," Science, 320, 643 (2008).

[3] B. Redding, M. A. Choma, H. Cao, "Speckle-free laser imaging using random laser illumination," Nat. Photonics, 6, 355 (2012).

[4] L. Wang, Xinyong Dong, P. P. Shum, X. Liu, and H. Su, "Random laser with multiphase-shifted Bragg grating in Er/Yb-codoped fiber," J. Lightwave Technol., 33(1), 95 (2015).

[5] S. D. Jackson, "Towards high-power mid-infrared emission from a fibre laser," Nat. Photonics, 6, 423 (2012).

[6] Y. Tang and J. Xu, "A random Q-switched fiber laser," Sci. Rep. 5, 9338 (2015).

[7] X. Jin, Z. Lou, H. Zhang, J. Xu, P. Zhou, and Z. Liu, "Random distributed feedback fiber laser at 2.1 μm," Opt. Lett. 41, 4923-4926 (2016).

[8] C. Huang, Xinyong Dong, N. Zhang, S. Zhang, and P. Shum, "Multi-wavelength Brillouin-erbium random fiber laser incorporating a chirped fiber Bragg grating," IEEE J. Sel. Top. Quantum Electron. 20(5), 0902405 (2014).

[9] Y. Xu, S. Gao, P. Lu, S. Mihailov, L. Chen, X. Bao, "Low-noise Brillouin random fiber laser with a random grating-based resonator," Opt. Lett. 41, 3197 (2016).