Thulium-doped fiber random laser operated at 1950 nm

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***Abstract*—A thulium doped fiber random laser pumped by 793 nm and operated at 1946.8 nm is presented. It uses a random fiber grating for distributed random feedback and a fiber loop mirror to form a half-open cavity structure to reduce the pump threshold. Random laser with threshold power of 2.3 W and optical-signal-to-noise ratio of 38 dB is obtained.**

Keywords-thulium doped fiber; random laser; random fiber grating

I. Introduction

Random fiber lasers (RFL) have been widely studied based on various disordered media for their advantages of simple structure and unique nature [1,2]. Most of the reported RFLs were enabled by the combination of amplification from stimulated Raman/Brillouin effect in optical fibers and random distributed feedback from backward Rayleigh scattering in long fibers [3,4]. Their pump threshold powers are normally high. RFLs by using active fibers, such as erbium-doped fiber, have also be developed and featured by much lower threshold pump power [5].

RFLs covering 1.0-1.5 μm wavelength range have been extensively studied [6]. However, RFLs at 2 μm are rarely reported and difficult to achieve because of the following two facts. First, the transmission loss in normal silica fibers is very large, ~30 dB/km, at 2 μm. Second, the Rayleigh scattering efficiency, inversely proportional to the fourth power of wavelength, is much lower at 2 μm than that at 1 or 1.5 μm.

In this work, we demonstrate a random fiber laser by using a thulium-doped fiber as the gain medium [7] and a random fiber grating for random distributed feedback [8]. Laser output at the wavelength of 1946.8 nm with optical-signal-to-noise ratio of 38 dB has been achieved.

II. Experimental setup

The proposed RFL, as shown in Figure 1, is formed by a 793 nm pump laser with maximal output power of 15 W, a 793/2000 nm wavelength-division multiplexer (WDM), a fiber loop mirror, a 1.5 m-long thulium-doped fiber and a random fiber grating.

The RFL has a half-open cavity design because of the fiber loop mirror. The random fiber grating was inscribed on a normal silica fiber by using a femtosecond laser. It contains over 6000 randomly spaced refractive index modulation spots distributed along 10 cm length of a single-mode fiber, providing distributed random feedback with enhanced Rayleigh scattering efficiency [9]. The output of the RFL is monitored by using an optical spectrum analyzer with wavelength resolution of 0.1 nm and an optical power meter.

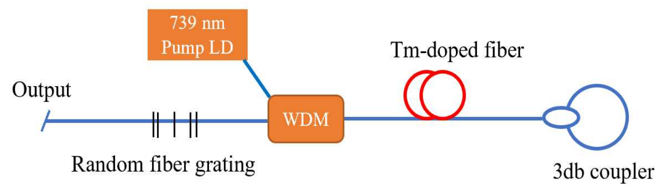

Figure 1. Experimental setup of the proposed random fiber laser.

III. Results and Discussion

Several measured output spectra of the random fiber laser are shown in Figure 2. When the pump power reached the threshold power, 2.3 W, a lasing peak was obtained at 1946.8 nm. As pump power was increased, the laser become stable. The optical-signal-to-noise ratio is up to 38 dB when the pump power was 3.5 W.

Figure 3 shows the measured laser output power against injected pump power. The threshold power of the random fiber laser is 2.3 W, which is obviously lower than that of the 2.1 μm RFL based on the Raman gain in a 150 m GeO_2-doped fiber reported in [10]. When the pump power exceeds the threshold power, the output power increases linearly with increasing pump power. The slope efficiency is ~2%.

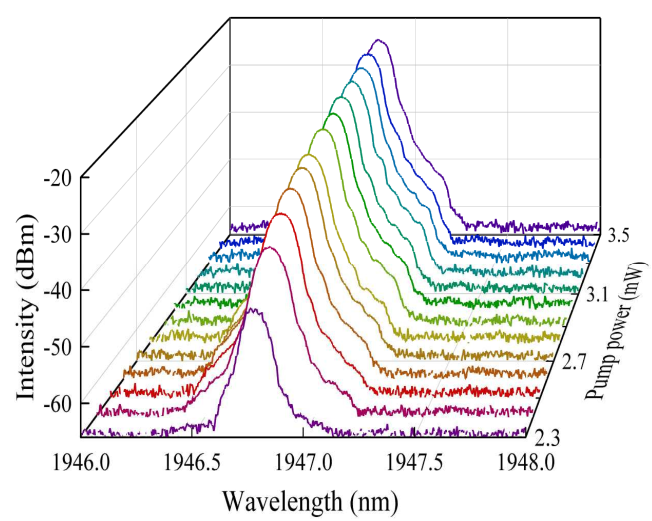

Figure 2. Optical spectra of laser output.

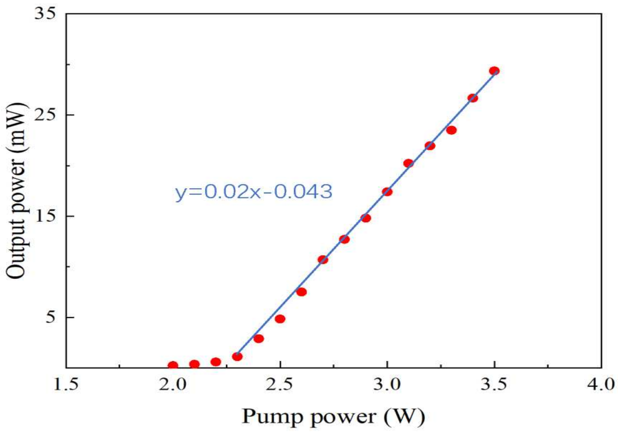

Figure 3. Output power of the RFL as a function of pump power.

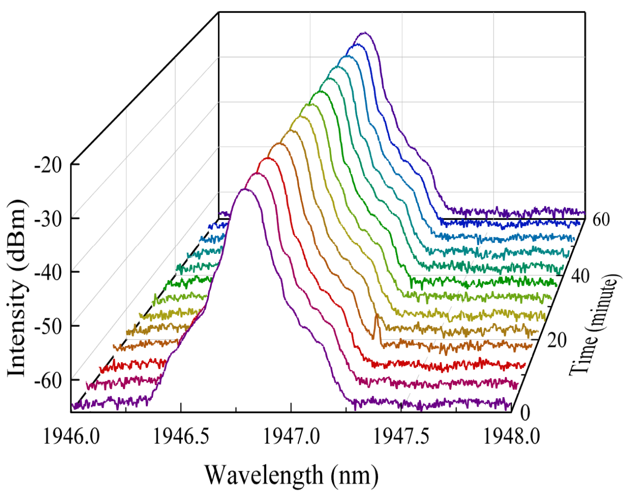

Figure 4. Laser output spectra measured within 60 minutes when pump power is 3.5 W.

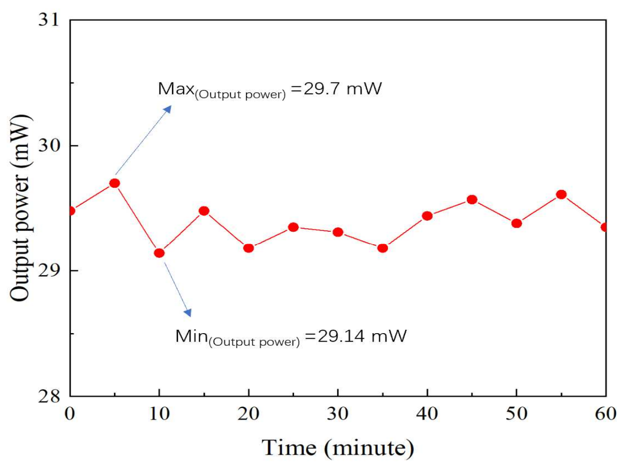

Figure 5. Output power fluctuations within 60 minutes when pump power is 3.5 W.

To test stability of the random fiber laser, laser output spectra and power were measured within 60 minutes at an interval of 5 minutes, when the pump power is 3.5 W. Figure 4 shows the laser output spectra wavelength shift of the random fiber laser is less than 0.1 nm, which equals to the wavelength resolution of the optical spectrum analyzer. So, the wavelength stability is quite good.

Figure 5 shows the measured output power fluctuation of the random fiber laser. It can be seen that the maximum laser output power is 29.7 mW and the minimum is 29.14 mW. The fluctuation is less than 0.6 mW in an hour.

IV. Conclusion

We reported a thulium doped fiber-based random laser operated at 1946.8 nm by using a random fiber grating as the distributed random feedback medium. Stable laser output with pump power threshold of 2.3 W and high optical-signal-to-noise ratio of 38 dB was obtained. The pump power threshold is much lower than that of the previously reported 2-μm random fiber lasers.

Acknowledgment

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