A Picosecond Mode-Locked Yb Fiber Laser with Shot-Noise-Limited Intensity Noise and Multi-Milliwatt Output Power

Univ. of Tokyo[1], °G. Dai.[1], K. Katoh[1], Y. Ozeki[1]

E-mail: dgy@ginjo.t.u-tokyo.ac.jp

Mode-locked fiber lasers have shown significant advantages on heat dissipation, cost, compactness and stability. Thus, they are considered as practical laser sources for a variety of applications such as optical communications, optical frequency combs, and biomedical imaging [1, 2]. However, previous mode-locked fiber lasers have low output power (<1 mW) [3] and a large amount of excess noise due to amplified spontaneous emission (ASE) noise can dominate, which hinders their application to precise optical measurement that requires shot-noise-limited intensity noise [4, 5].

In this paper, we present a low-intensity-noise polarization-maintaining Yb fiber laser generating multi-milliwatt picosecond pulses based on figure-nine configuration [6,7] as shown in Fig. 1(a). The output coupling ratio is as low as 10% in order to minimize cavity loss. The distance between the transmission gratings is set to ~10 cm, introducing large group velocity dispersion (GVD) so as to increase the pulse duration to picosecond regime and to increase the pulse energy [7]. The mode-locking is self-starting when the pump power is 350 mW, then we reduce the pump power to ~300 mW to realize single-pulse mode-locking state. The wavelength of the output pulses was 1038 nm, the average power was 3.3 mW, and the repetition rate was 30 MHz. The pulse duration was measured to be 3.3 ps with a time-bandwidth product of 0.53 by assuming sech^2 pulse shape.

Fig. 1(b) shows the intensity noise of the laser pulses measured as a function of optical power. We calculated the theoretical value of thermal noise and shot noise by assuming the signal loss of 1.1 dB, shown by solid black and red line in Fig. 1(b), whereas the amount of excess noise was used as a free parameter to fit the experimental result with the sum of the three kinds of noise mentioned above. The fitting result, shown by dashed red curve in Fig. 1(b), coincides well with the experiment result. It is clear that the estimated excess noise, which is expressed by the solid blue line in Fig, 1(b), is suppressed under the shot-noise level when the power is lower than ~5.5 mW, proving the laser is nearly short-noise-limited at multi-milliwatts power regime.

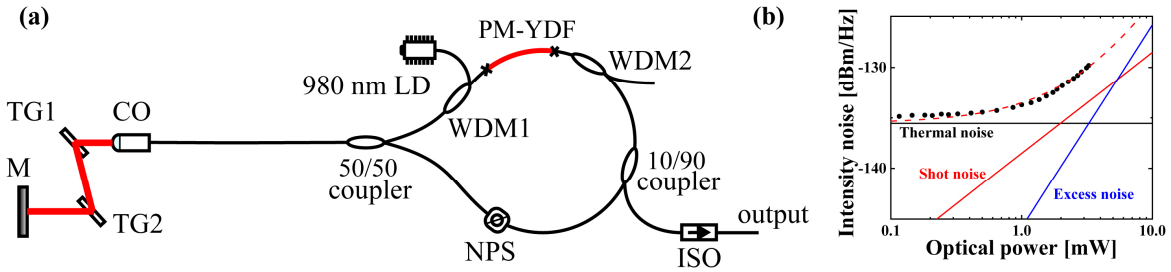

Fig. 1. (a)The schematic of PM Yb fiber laser. NPS: non-reciprocal phase shifter [5]. ISO: isolator. WDM: wavelength-division multiplexer. LD: laser diode. CO: collimator. TG: transmission grating. M: mirror. (b) Intensity noise at 7 MHz measured as a function of optical power.

References

[1] C. Xu *et al.*, Nat. Photon. **7**, 875 (2013).
[2] Y. Ozeki *et al.*, Nat. Photon. **6**, 845 (2012).
[3] J. Chen *et al.*, Opt. Lett. **32**, 1566 (2007).
[4] I. Coddington *et al.*, Optica **3**, 414 (2016).
[5] Y. Ozeki *et al.*, IEEE J. Sel. Top. Quantum Electron. **25**, 7100211 (2019).
[6] N. Kuse *et al.*, Opt. Express **24**, 3095 (2016).
[7] H. Yoshimi *et al.*, Jpn. J. Appl. Phys. **57**, 108001 (2018).