All-fiber Mode-locking Laser using Low-V-number Fiber with enhanced Polarization Dependent Loss

The University of Tokyo [1], ○Yunpeng Huang [1], Hongbo Jiang [1], Zihao Zhao [1], Takuma Shirahata [1], Lei Jin [1], Sze Y. Set [1] and Shinji Yamashita [1]

E-mail: yphuang@cntp.t.u-tokyo.ac.jp

Abstract: We propose and demonstrate, for the first time, a stable all-fiber thulium-doped mode-locked laser using a low-V-number fiber to generate a sufficient amount of polarization dependent loss for nonlinear polarization rotation.

1. Introduction

Among various kinds of passively mode-locking [1, 2], nonlinear polarization rotation (NPR) mode-locking method has its superior features such as all-fiber structure and high-power tolerance. In this paper, instead of utilizing conventional polarizer or a polarization-dependent isolator [3], we propose to generate and control a sufficient amount of PDL without compromising to bend loss by using a low-V-number fiber (LVF) coil. SM1950 operating in 2 μm has a V number of 2.27, which we consider as normal-V-number fiber (NVF). When SMF28 is operated in the wavelength of 2 μm, the V number is 1.74, which is considered as LVF.

2. Characteristics of LVF and NVF

We measure the bend loss and the PDL of LVF (SMF28) and NVF (SM1950) in 2 μm wavelength, which are uniformly coiled around several metal cylinders with different radii from 18 mm to 25 mm. The measurement system shown in figure 1(a) is based on the polarization scanning method. According to the result of bend loss (red marks) and PDL (blue marks) depicted in figure 1(b), we believe LVF is more suitable for bend-induced PDL generation. However, LVF coils become too lossy to be a mode locker when the r < 20 mm.

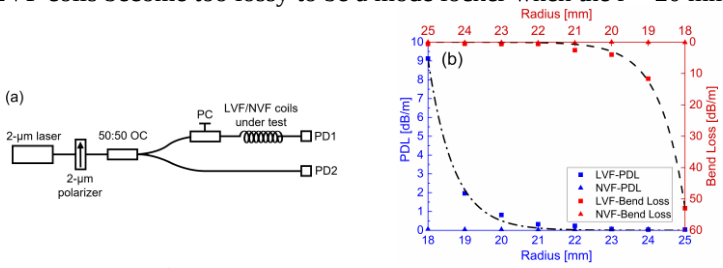

Fig.1. (a) Schematic of measurement system. (b) PDL and bend loss measurement results

3. Mode-locking demonstration

Figure 2(a) shows the schematic of experimental setup using an LVF coil with r = 20 mm as the polarizing element. A 3-meter-long thulium-doped fiber (TDF) is used as the laser gain medium. The total length of cavity is about 15 m. By properly adjusting the PCs, we can easily get fundamental or harmonic mode-locking. All the results in figure 2 are recorded in the stable fundamental mode-locking state.

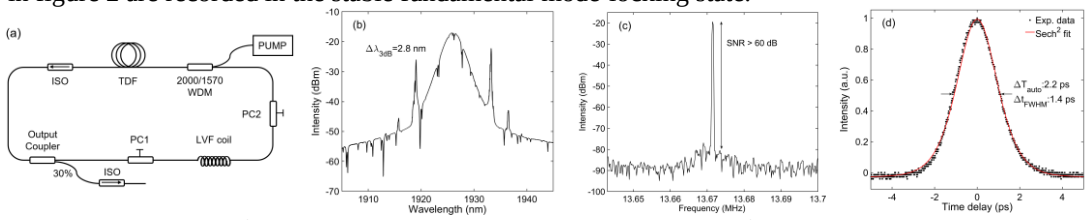

Fig. 2. (a) All-fiber mode-locking setup with LVF. (b) Output spectrum of the mode-locked laser. (c) The RF spectrum and (d) the autocorrelation trace of the fundamental soliton pulses.

4. Conclusion

We demonstrate, for the first time, an all-fiber CW mode-locked fiber laser by utilizing a segment of bending LVF as a polarizing element. We found that a PDL around 1.07 dB is the smallest PDL sufficient for the initiation of stable CW mode-locking. We also believe this weak-guiding effect can be extended to many other wavelengths such as using SM780 in ytterbium-doped fiber laser systems and using HI1060 in Erbium-doped fiber laser systems, which can make it easier to realise stable NPR mode-locked fiber lasers with superior features in an all-fiber and cost-effective manner.

Acknowledgement

This work was supported by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (S) 18H05238 and Scientific Research (B) 19H02149.

[1] L. Nelson, D. Jones, K. Tamura, H. Haus, and E. Ippen, “Ultrashort-pulse fiber ring lasers,” Appl. Phys. B **65**, 277-294, (1997).
[2] M. E. Fermann and I. Hartl, “Ultrafast fibre lasers,” Nat. Photonics **7**, 868-874, (2013)
[3] H. A. Haus, E. P. Ippen and K. Tamura, "Additive-pulse modelocking in fiber lasers," in IEEE J. Quantum Electron **30**, 200-208, (1994).