Tunable L-band Mode-Locked Bi-EDF Fiber Laser Based on Chirped Fiber Bragg Grating

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Abstract: A tunable L-Band mode-locked fiber laser based on a short Bismuth-based Erbium-doped fiber is presented. A chirped fiber Bragg grating (CFBG) centered at ~1600.9 nm was used both as a spectral filter and as a dispersive device. Stable mode locking operation was demonstrated with average output power of 2.85 mW. The optical pulses have width and repetition rate of 7.43 ps and 12.8 MHz, respectively. By mechanically tuning the CFBG, the central wavelength of the mode-locked laser can be tuned between 1599.1 and 1602.5 nm.
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1. Introduction

Ultrafast fiber lasers operate at L-band have many important applications, such as optical fiber communications, coherent Raman scattering microscopy, and terahertz generation. To obtain efficient gain at L-band, long Erbium-doped fibers of several tens of meters were required[1-3]. However, long-cavity lasers are usually susceptible to environmental perturbation and exhibit low repetition rates. The limitation can be overcome by using Bismuth-based Erbium-doped fiber (Bi-EDF), which has high Er^{3+} concentrations of over 3000 ppm/wt and thus can achieve high gain in the L-band using short fiber length[4,5]. Also, spectral filters are commonly used to ensure lasing at L-band and fiber grating filters are very effective for use as in-cavity spectral filtering at any communication wavelengths[6].

In this paper, we present a wavelength-tunable L-band mode-locked fiber laser using a short length of Bi-EDF and a single-walled carbon nanotube (SWCNT) saturable absorber. A CFBG centered at L-band was fabricated and used for both spectral filtering and dispersion compensation. Stable mode-locked laser will be demonstrated at ~1600 nm with pulse duration of 7.423 ps. Spectral tuning of the mode-locked laser is achieved by mechanically tuning the CFBG.

2. Experiment setup

Fig. 1(a) illustrates the experimental setup of the L-band mode-locked fiber laser and optical spectrum of the fabricated CFBG. The configuration consists of a Bi-EDF, a 10-dB output coupler, a polarization controller (PC), a polarization-dependent isolator (PDI), a CFBG and a compact all fiber saturable absorber. The gain fiber is a 101.3-cm long Bi-EDF with Er^{3+} doping concentration of 6500 ppm/wt, and is forward pumped by a Raman laser at 1475 nm through a division multiplexing (WDM) coupler. The 10% fiber coupler is used to tap laser output. The PC is used to optimize the intra-cavity polarization state. The fiber isolator is to ensure unidirectional operation of laser. The compact all fiber saturable absorber was realized by inserting a SWCNT doped polymer film between two angled physical contact fiber connectors (FC/APC). The CFBG was incorporated into the laser cavity via a fiber circulator. To minimize cavity loss, a high-reflectivity CFBG was employed. The CFBG was fabricated with a Talbot interferometer and a 213-nm pulsed solid-state laser. As shown in Fig.1 (b), the central wavelength and 3-dB bandwidth of the CFBG are 1600.9 nm and 2 nm, respectively. The reflectivity of the CFBG at the central wavelength is around 99%. A plastic cantilever was used to mechanically tune the spectra of the CFBG.

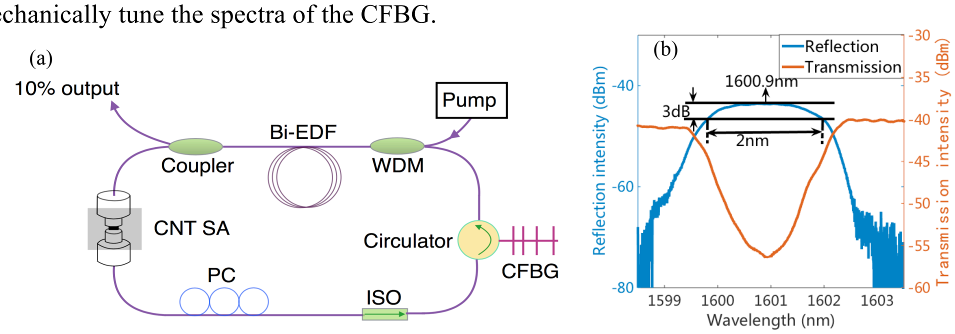

Fig. 1. (a) Schematic of the L-Band mode-locked Bi-EDF fiber laser and (b) the optical spectra of the fabricated CFBG used in the experiments.

3. Results and discussion

In the experiment, the fiber laser cavity was initially pumped without the CFBG device. Self-start mode locking was observed when the pumping power was increased to 165 mW. The orientation of the PC was appropriately tuned to stabilize the laser output. Fig. 2 (a) shows the measured laser spectrum whose central wavelength and 3-dB bandwidth are 1596.1 nm and 7.9 nm, respectively. The distinct Kelly sidebands indicate laser operation in the anomalous dispersion regime. The pulse-to-pulse separation is 62.3 ns, which corresponds to a repetition rate of 16.05 MHz. Fig. 2(c) shows the autocorrelation trace of the output pulses recorded by an optical autocorrelator. With the assumption of a sech2 profile, the pulse width is estimated to be ~558.4 fs.

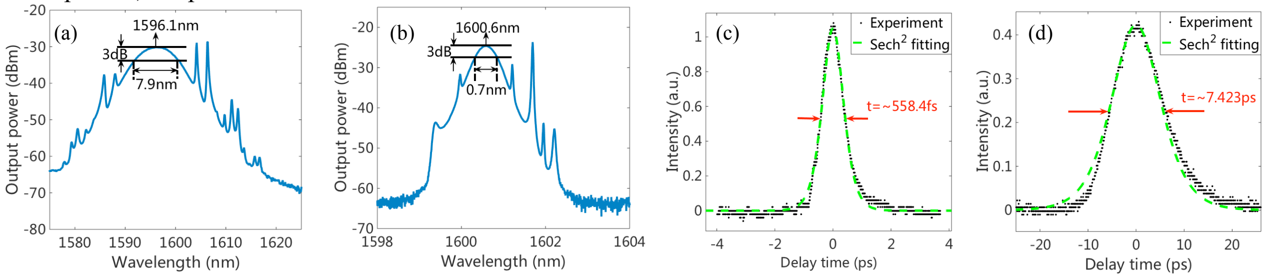

Fig.2. Optical spectrum of the mode-locked fiber laser (a) without and (b) with CFBG and autocorrelation trace of the output pulses of the mode-locked fiber laser (c) without and (d) with CFBG.

With all other components unchanged, the own-fabricated CFBG was incorporated into the laser cavity through a fiber circulator. The CFBG was inserted in the laser cavity to operate in the anomalous dispersion direction. Experimental results showed that mode locking can self-started at the high pumping power of about 200 mW. Fig. 2(b) shows a typical output of the mode-locked laser with CFBG. The pumping power of the laser was ~197 mW. The central wavelength and 3-dB bandwidth of the laser output are 1600.6 nm and 0.7 nm, respectively. The asymmetric spectral is induced by inhomogeneous gain distribution around the grating reflective band and spectral filtering effect of CFBG. The average output power is 2.85 mW. The repetition rate of the output pulses is 12.8 MHz. The measured pulse duration is ~7.423 ps as shown in Fig. 2(d). The broadened pulse width is attributed to the narrow bandwith and anomalous dispersion of the CFBG.

By using the mechanical cantilever, the central wavelength of the CFBG filter can be finely tuned. Consequently, the output spectrum of the mode locked laser can be continuously tuned with the pumping power and the orientation state of the PC remain unchanged. Fig. 3 shows the measured spectra of the mode-locked laser whose central wavelength was tuned from 1599.1 to 1602.5 nm. Stable mode locking was observed during the tuning process.

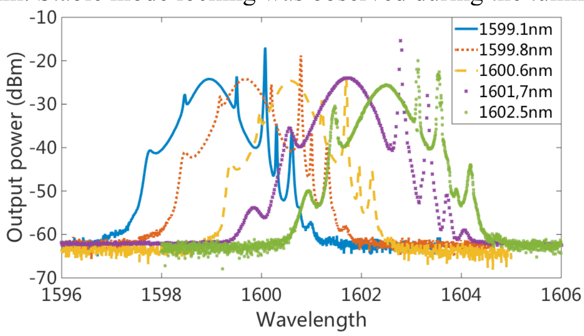

Fig. 3. Optical spectra of the L-band fiber mode-locked laser tuning with the CFBG.

4. Conclusions

In conclusion, we have demonstrated a spectrally tunable mode-locked Bi-EDF fiber laser by using a CFBG. The average output power, pulse width, and repetition rate of the laser are 2.85 mW, 7.423 ps and 12.8 MHz, respectively. The central wavelength of the laser output can be continuously tuned from 1599.1 to 1602.5 nm.

5. Acknowledgement

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6. References

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