Nanjing University of Posts and Telecommunications

Mode-locked laser with high-order mode generation based on grating combiner

Yaqiong Lu, Shaokang Bai, and Zuxing Zhang

Advanced Photonic Technology Lab, College of Electronic and Optical Engineering & Microelectronics College, Nanjing University of Posts and Telecommunications, Nanjing 210023, China

Corresponding author: zxzhang@njupt.edu.cn

ABSTRACT

Mode-locked laser with high-order mode generation based on grating combiner:

Keywords: fiber Bragg grating, long-period fiber grating, cylindrical vector beam

We propose and demonstrate an all-fiber passively mode-locked laser that generates high-order mode. A grating combiner of a few-mode long-period fiber grating and a few-mode fiber Bragg grating are introduced into the laser cavity to achieve the purposes of mode conversion and mode selection.

INTRODUCTION

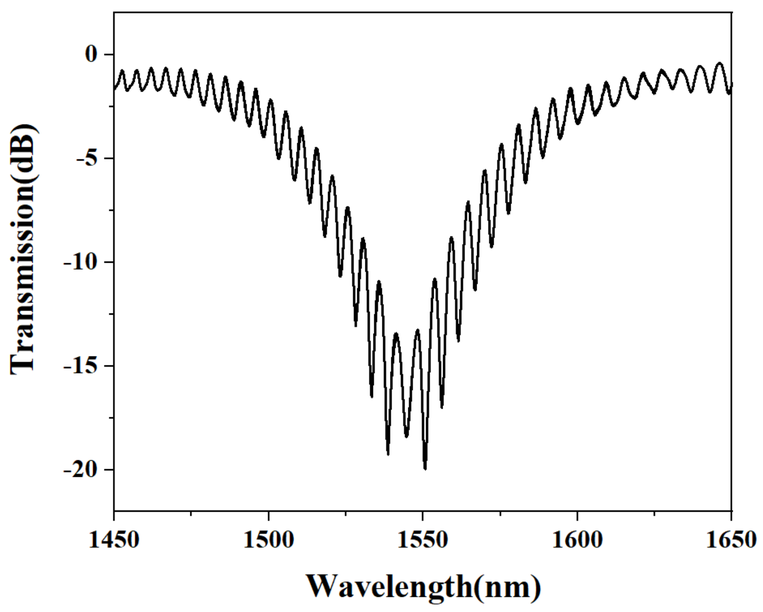
Methods to generate high-order modes

- offset splicing of SMF and FMF
- combine the SMF and the FMF into MSC by fusion and taper
- write long-period fiber grating (LPFG) on TMF by CO_2 laser

Advantages of using the grating combiner

- the TM-LPFG as mode converter and the TM-FBG as mode selector
- high mode conversion efficiency
- the purity of CVB is higher than that of single mode converter

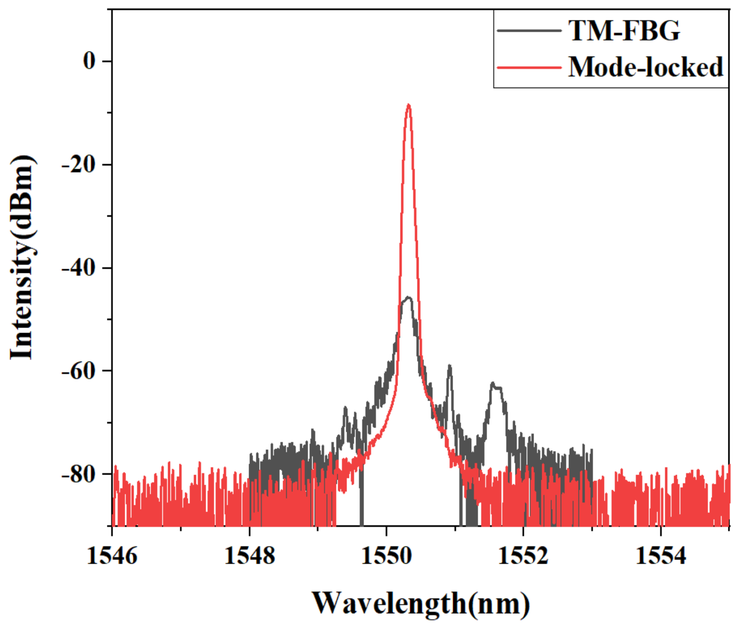
CHARACTERISTICS OF TM-LPFG



The TM-LPFG is inscribed on TMF (OFS, two-mode step index fiber, 19/125μm). The measured loss peak represents the intensity of mode conversion efficiency, as shown in Fig. 2. The efficiency is higher than 90% (10 dB) with a range of 27 nm (1531 nm~1558 nm) and the peak efficiency is about 99% (20 dB) at 1550.6 nm.

Fig. 1. Measured transmission spectrum of the TM-LPFG.

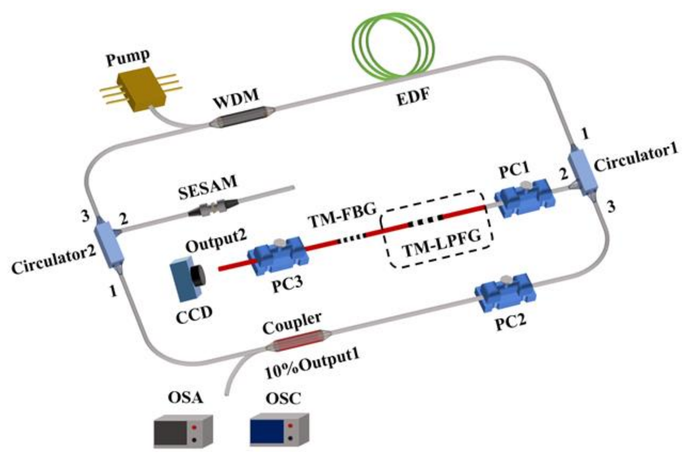
CHARACTERISTICS OF TM-FBG



The black curve of Fig.3 shows the reflection spectrum of the TM-FBG. Among them, the self-coupling between LP11 and LP11 modes corresponding to the left reflection peak is the highest, which also indicates that the mode conversion of the TM-LPFG still has a high efficiency under broadband. The red curve in Fig.3 shows the mode-locked spectrum with a 3dB spectrum width of 0.08 nm at 1550.3 nm.

Fig.2. Reflection spectrum of the TM-FBG (black line) and the output spectrum of the laser (red line) at 400mW pump power.

EXPERIMENTAL SETUP



The ring cavity structure uses an fiber circulators to control unidirectional transmission, and SESAM implements passively mode locking. The combination of the TM-LPFG and the TM-FBG can achieve high purity CVB output. The total length of the cavity is 15.5m.

Fig. 3. Experimental setup of the all-fiber mode-locked laser with high-order mode generation.

RESULTS AND DISCUSSIONS

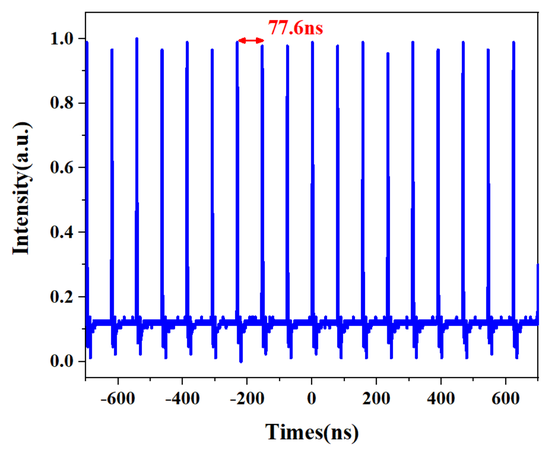


Fig.4. Mode-locked pulse train.

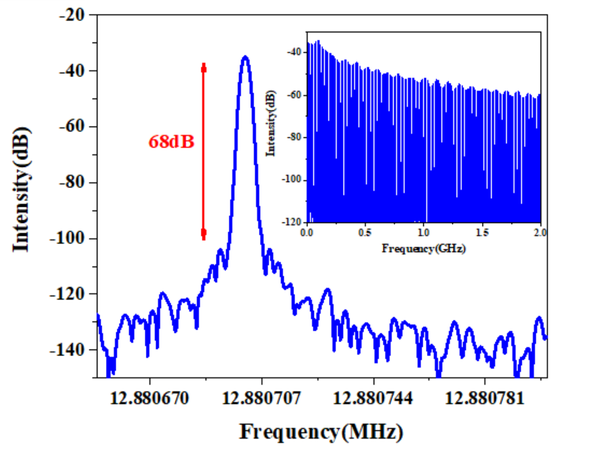
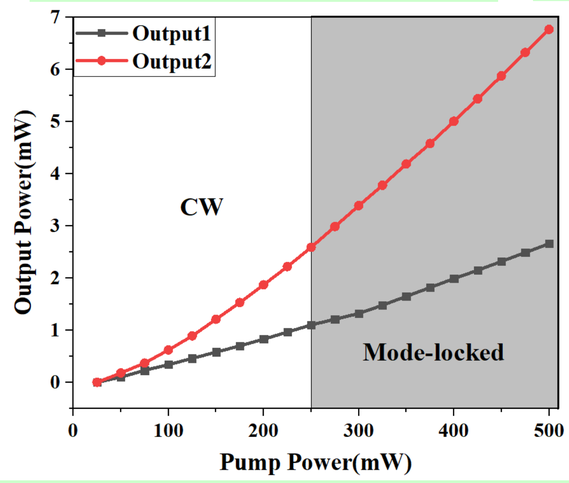


Fig.5. RF spectrum of the mode-locked pulse.



By adjusting the PC1 and PC2, we can observe the stable pulse sequence with an interval of 77ns between two adjacent pulses. The fundamental repetition frequency is 12.88MHz and the SNR is exhibited higher than 68dB. The calculated slope efficiency of Output1 and Output2 is about 0.55% and 1.67%, respectively.

Fig.6. The relationship between output power and pump power.

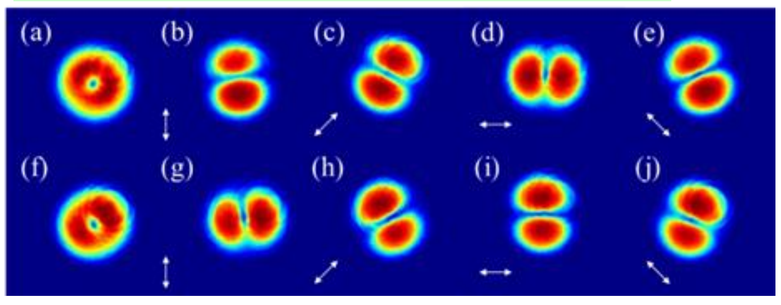


Fig.7. Intensity distribution of (a) the azimuthally polarized beam and (b)-(e)after passing through a polarizer, (f) the radially polarized beam and (g)-(j) after passing through the polarizer. The white arrows represent the direction of the linear polarizer.

CONCLUSION

An all-fiber passively mode-locked laser using the TM-LPFG to accomplish mode conversion is proposed and demonstrated. Combined with the TM-FBG, we realize the output of mode-locked CVB pulse. The purity of the radial polarization and azimuth polarization vector beams are both measured higher than 95%. This laser could be the high efficiency CVB source for practical applications.

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