Triple-wavelength EDF laser employing sampled fiber grating and PMF

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A novel triple-wavelength erbium-doped fiber laser employing linear cavity structure was presented and demonstrated experimentally. Cavity mirrors of the laser were composed of two left and right Sagnac loops. Left loop was formed by a fiber coupler (FC) with power ratio of 50:50, a sampled fiber grating (SFG) and a three-ring-type polarization controller (PC). Two adjacent transmission peaks of the SFG had 0.3 nm wavelength spacing. Right loop consisted of a same FC and a length of panda-type polarization-maintaining fiber (PMF). The two loops had different transmission spectra. They formed a couple of comb filters to mutually produce the multiple wavelengths. After the PC was tuned to cause the PHB effect, the laser could output three kinds of different lasing lines including single-wavelength, dual-wavelength, and triple-wavelength. All of lasing lines had more than 33 dB optical signal-noise-ratio and less than 0.67 nm linewidth.

1. Introduction

In recent years, multi-wavelength fiber lasers (MWFLs) have received increased attention because they played a crucial role in many important fields, for instance, fiber sensors, and DWDM optical communications at so on [1–6].

In order to achieve stable multiple wavelength output in the erbium-doped fiber laser (EDFL), various schemes were proposed, such as modified Mach-Zehnder interferometer [7], hybrid structure optical fiber filter [8], and triple-core photonic crystal fiber [9].

Because sampled fiber grating (SFG) has asymmetrical transmission spectrum, it is not employed commonly in the MWFL. Polarization-maintaining fiber (PMF) is often used in the ring cavity to select wavelength. SFG and PMF have different transmission spectra. If they are used in a laser, output wavelength would appear new superposition phenomena. Therefore this paper plans to investigate the phenomena. A triple-wavelength (TW) EDFL using linear cavity is presented and experimentally demonstrated. Left loop with an SFG and right loop with a length of PMF are employed to mutually produce multi-wavelength. This laser obtains three sorts of diverse lasing lines.

2. Experiment

The structural diagram of the TW-EDFL was displayed in Fig. 1. It employed linear cavity structure which consisted of left and right Sagnac loops. A 3 dB fiber coupler (FC), a three-ring-type polarization controller (PC) and an SFG were inserted in the left loop. A length of 2 m panda-type PMF and other same 3 dB FC were inserted in the right loop.

A 980 nm laser diode (LD) was used as pump source. By a 980/1550 wavelength division multiplexing (WDM) coupler, 980 nm beams input the laser cavity to excite 5 m EDFs that were made by Fibercore Limited Company.
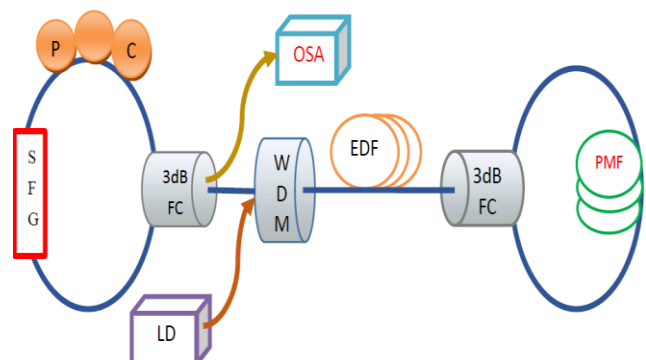

Fig. 1. Structural diagram of the TW-EDFL (color online)

3. Results and discussion

In the left loop, the SFG has transmission spectrum as shown in Fig. 2. Two adjacent transmission peaks have approximately 0.3 nm wavelength spacing and the maximum modulation depth attains to 8 dB. Its overall insertion loss is only 0.6 dB. In the right loop, according to the work principle of Sagnac loop with PMF [10], the high birefringence of PMF is able to make the propagating lights form phase difference δ.

$$\delta = (2\pi BL)/\lambda \qquad (1)$$

Hence, the power transfer function of the Sagnac loop is periodic,

$$T(\lambda) = \sin^2(\delta/2) \qquad (2)$$

The wavelength spacing of two neighboring transmission peaks in the Sagnac loop is following as

$$\Delta\lambda = \frac{\lambda^2}{(BL)} \qquad (3)$$

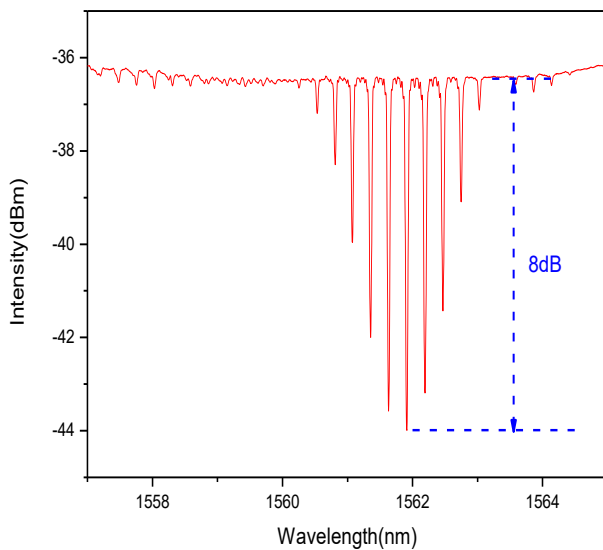where λ is the optical wavelength, B is the modal birefringence, and L is the length of PMF.

Fig. 2. Transmission spectrum of the SFG (color online)

When the pump power is fixed at 350 mW, pump threshold of this laser is 50 mW and the corresponding output power attains to 5 mW. Output lights of the left loop are measured by an optical spectrum analyzer (OSA) with 0.02 nm minimum resolution.

Work principle of this laser is as following. When the PC is adjusted slowly, propagating lights through the PC can change their polarization states. Firstly, loss related with polarization will be produced. The polarization hole burning (PHB) effect will happen. Secondly, gain and loss of diverse wavelengths will happen to change. When gain of one wavelength is greater than its loss, this wavelength will produce. Otherwise, it will disappear. Thus the amount of lasing lines will change continually. Finally, under the cooperation of the SFG and PMF, three kinds of diverse lasing lines are achieved. These lines are displayed in Figs. 3, 5, 6. Meanwhile, the stabilities of their wavelength and peak power are measured.

After the PC is slowly adjusted, the laser outputs a sort of triple-wavelength lasing line as shown in Fig. 3. Fig. 3 displays its five-times repeated scan spectra. The wavelengths of three lasing lines locate the 1527.08 nm, 1530.51 nm and 1531.41 nm, respectively. The lasing wavelengths are far away from the transmission spectrum of the SFG. There are two possible reasons. Firstly, the filtering performance of PMF can also influence the location of the lasing wavelength and produce to shift. Secondly, by the rotation of PC, polarization states of different wavelength light can produce changes and cause PHB effect. Then the wavelength location can be shifted. All of lines have more than 33 dB optical signal-noise-ratio (OSNR). They have peak power difference of less than 10 dB and less than 0.57 nm linewidths. From the Fig. 3, it can be seen that the summits of two right lasing lines appear some small peaks. The narrow transmission peaks of the SFG can cause this phenomenon.
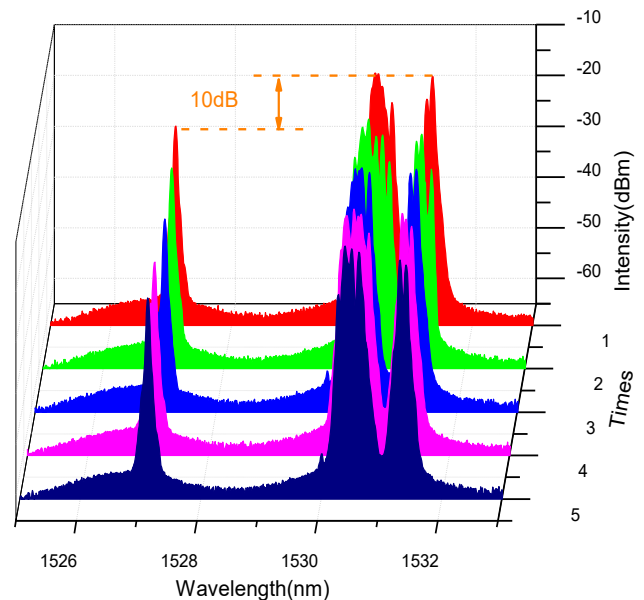

Fig. 3. Five-times repeated scan spectra of the triple-wavelength (color online)

Fig. 4 displays power stabilities of three peaks across time. The maximum and minimum peak-power differences of the 1531.41 nm and 1527.08 nm lasing lines during the 50 minutes are 2.9 dB and 1.5 dB, respectively.
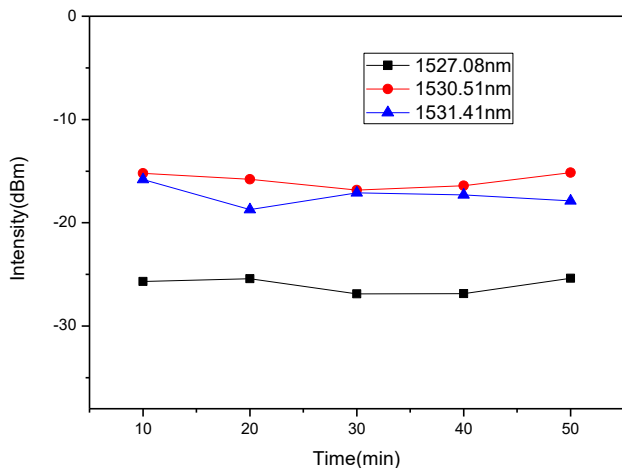
Fig. 4. Power stabilities of three peaks across time (color online)

Fig. 6. Single-wavelength spectrum (color online)

When we further turn the PC, the laser can output another dual-wavelength lasing lines as shown in Fig. 5. The wavelengths of two lasing lines locate at the 1526.80 nm nm and 1530.97 nm, respectively. The 1526.80 nm lasing line has the OSNR of 37 dB and 0.19 nm linewidth. The 1530.97 nm lasing line has the OSNR of 50dB and 0.42 nm linewidth. The power difference of two peaks is approximately 12 dB.
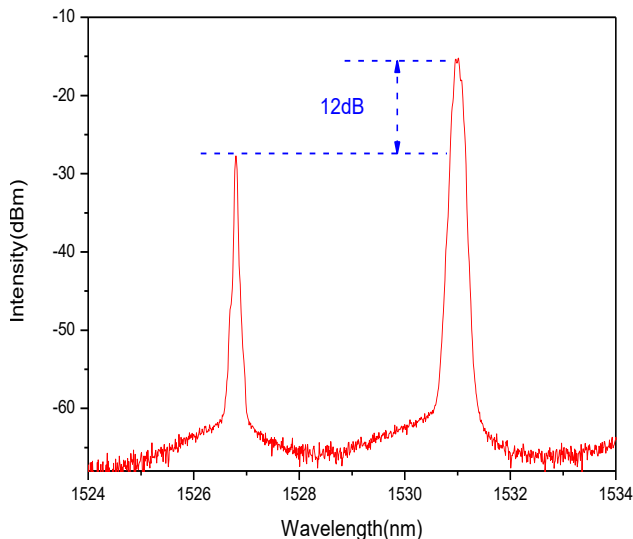
4. Conclusion

A TW-EDFL employing linear cavity structure is presented and experimentally demonstrated. Two Sagnac loops including an SFG and a length of PMF are employed mutually to excite multi-wavelength output. After we slowly adjust the PC, three sorts of diverse lasing lines including single-wavelength, dual-wavelength and triple-wavelength are achieved.

Fig. 5. Dual-wavelength spectrum (color online)

When the PC is adjusted carefully, the laser also outputs a single-wavelength lasing line as shown in Fig. 6. The wavelength of the lasing line locates at 1530.43 nm. It has 0.67 nm linewidth and 50 dB OSNR. It can be seen that peak summit appears four small peaks. It shows that mode competition is greater.
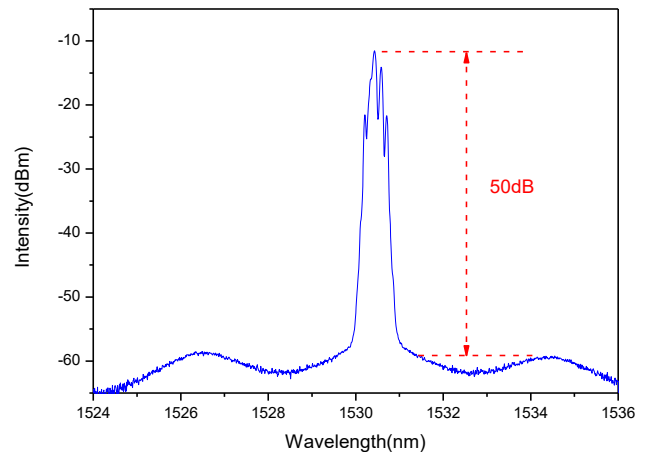
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