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Dual-wavelength EDF laser outputing six kinds of different lasing lines

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A novel switchable dual-wavelength erbium-doped fiber laser using a linear cavity structure was proposed and experimentally demonstrated. Cavity mirrors of this laser consisted of two Sagnac loops. The left loop consisted of a 3 dB fiber coupler (FC), a three-rings type of polarization controller (PC) and a phase shifted fiber grating. The right loop consisted of other same 3 dB FC and a length of 2 m panda-type polarization-maintaining fiber. The two loops became two comb filters to jointly produce the multi-wavelength output. After the PC was adjusted slowly, the laser could switch flexibly to output six kinds of different lasing lines. All of lasing lines had a narrow linewidth less than 1.12 nm and the optical signal-to-noise ratio of more than 37 dB.

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Keywords: Erbium-doped fiber laser, Phase shifted fiber grating, Polarization-maintaining fiber

1. Introduction

Recently, multi-wavelength fiber lasers have been research hotspots for their applications in many important fields, such as dense wavelength division multiplexing (DWDM) optical communication systems, optical fiber sensor systems, etc. [1–7].

In order to obtain stable multi-wavelength output, mode competition caused dy homogeneous broadening effect in the erbium-doped fiber have to be restrained. Thus various methods were proposed, such as a core-offset aluminum coated Mach-Zehnder interferometer [8], hybrid structure optical fiber filter[9], a triple-core photonic crystal fiber with polarization-dependent loss[10], Sagnac loop mirror [11] , and sputtered indium tin oxide as saturable absorber [12].

In this paper, a switchable dual-wavelength erbium-doped fiber laser (SDW-EDFL) using a simple linear cavity structure was proposed and experimentally demonstrated. Two Sagnac loops include a phase shifted fiber grating (PSFG) and a length of polarization-maintaining fiber (PMF), respectively. The loops are used as two wavelength-selection comb filters to jointly produce multiple wavelengths output. Six kinds of different lasing lines are obtained and can be switched flexibly one another.

2. Experiment

The stucture diagram of the proposed SDW-EDFL is shown in Fig. 1. The laser employs a backward pump scheme and a simple linear cavity structure. It consists of two Sagnac loops. The left loop is formed by splicing a PSFG, a three-rings type of polarization controller (PC), and two arms of a 3 dB fiber coupler (FC) with a power ratio of 50: 50. The right loop is formed by splicing a segment of 2 m panda-type PMF, and two arms of the other same 3 dB FC.

A laser diode (LD) has maximum output power of 400 mW and 976 nm central wavelength. It is used as a pump source of this laser. Pump light inputs the resonant cavity to pump a length of single-clad highly-doped EDF by means of a 980/1550 nm wavelength division multiplexing (WDM) coupler. The EDF was manufactured by Fibercore Limited Company and belonged the I-25 product in the IsoGainTM range. Its absorption coefficient at 980 nm is 27 dB m^{-1}.

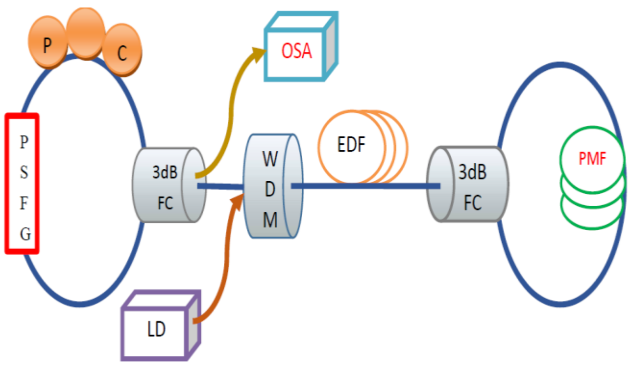

Fig. 1. Structure diagram of the laser (color online)

3. Results and discussion

In the left loop, the PSFG has transmission spectrum as shown in the Fig. 2. Two adjacent transmission peaks have about 0.2 nm spacing and the maximum modulation depth attains to 38 dB. In the right loop, according to the operating principle of Sagnac loop filter [13], the high birefringence of PMF can make the propagating beams produce a wavelength-dependent phase difference δ between the directions of the fast and slow axes in the PMF, that is

$$\delta = (2\pi BL)/\lambda \tag{1}$$

Thus, the intensity transfer function of the Sagnac loop filter is periodic, and is given as

$$T(\lambda) = \sin^2(\delta/2) \tag{2}$$

The wavelength separation between two adjacent transmission peaks of the Sagnac loop filter is given by

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

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

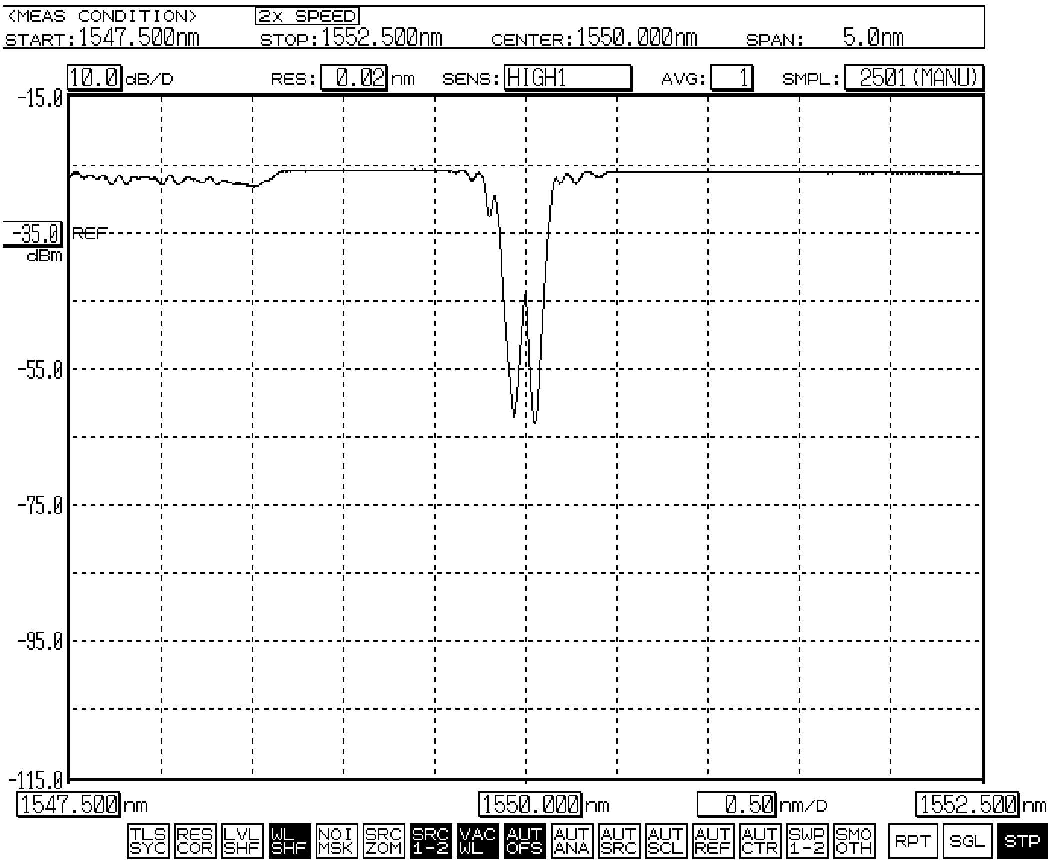

Fig. 2. Transmission spectrum of the PSFG

In the experiment, when the pump power was set at 380 mW, the spontaneous amplification emission light in the EDF kept on spreading back and forth in the resonant cavity. Under the joint roles of the PSFG and PMF, the multi-wavelength laser is extracted from the left loop and is measured by an optical spectrum analyzer (OSA) with a minimum resolution of 0.02 nm in the Fig. 1.

When the PC was rotated slowly, the polarization states of propagating lights in the fiber could happen to change. Then polarization-dependent losses could produce and the polarization hole burning (PHB) effect would appear. Losses of different wavelengths would happen to change. When the gain of one wavelength is more than its loss, this wavelength will be shown. Otherwise, it can disappear. Therefore the wavelength number is controlled. Ultimately, six kinds of different lasing lines are obtained and they were shown in the Figs. 3 and 6. At the same time, the stabilities of the peak power and wavelength of lasing lines are measured.

This laser has five kinds of dual-wavelength lasing lines as shown in the Fig. 3. The dual-wavelength parameters are shown in the Table 1. From the Fig. 3, it can be seen that the summits of some peaks appear some small peaks. It may be attributed to the narrow transmission peaks of the PSFG.

Meanwhile, the dual-wavelengths show some minor shifts. The possible reason is that the PC modulates propagating lights in the fiber. Through the rotation of the PC, the gain and loss of different dual-wavelengths can happen to vary. When the gain is less than the loss, some dual-wavelengths will disappear. Otherwise, some new dual-wavelengths will appear. So it causes the minor shift of different dual-wavelengths.

The role of the PSFG is to assist the PMF to produce the multi-wavelength. If it is removed, the laser cannot produce five kinds of dual-wavelengths.

Table 1. Dual-wavelength parameters. OSNR is the optical signal-to-noise ratio, MDPP is the maximum difference of peak power.

Figure	OSNR(dB)	3 dB linewidth (nm)	MDPP (dB)	Wavelength (nm)
3(a)	≥ 40	≤0.54	≤15	1527.00, 1530.88
3(b)	≥37	≤ 0.61	≤10	1530.51, 1533.07
3(c)	≥ 45	≤0.75	≤ 4	1530.50, 1534.59
3(d)	≥45	≤ 0.96	≤ 1	1530.11, 1534.03
3(e)	≥38	≤ 1.12	≤17	1526.65,1531.00

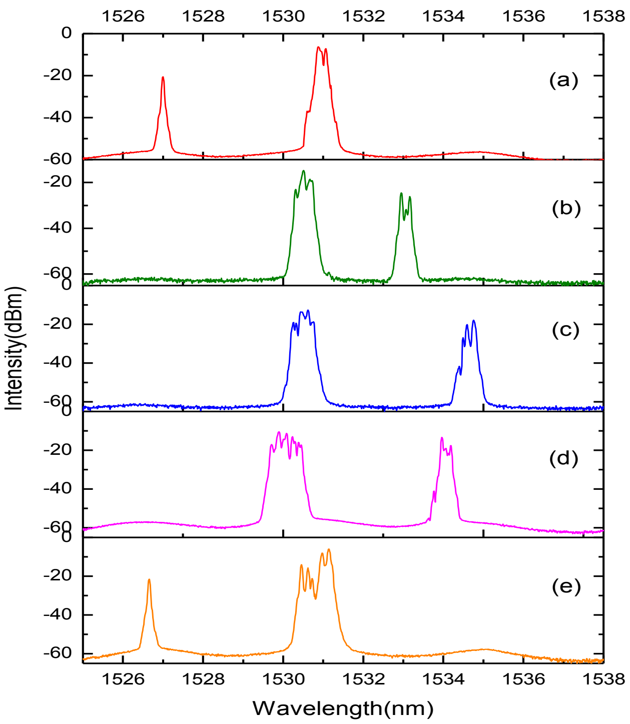

Fig. 3. Switchable dual-wavelength output spectra (color online)

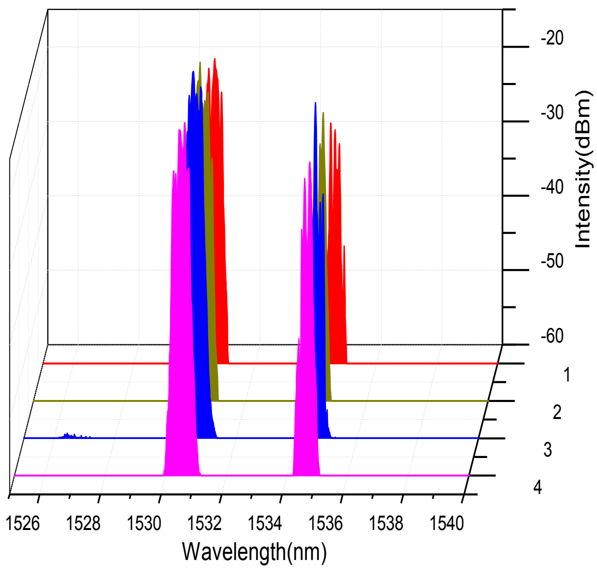

Fig. 4. Four-times repeated scan spectra of the Fig. 3(c) (color online)

Four-times repeated scan spectra of the Fig. 3(c) are shown in the Fig. 4. It can be seen that wavelength stabilities are better.

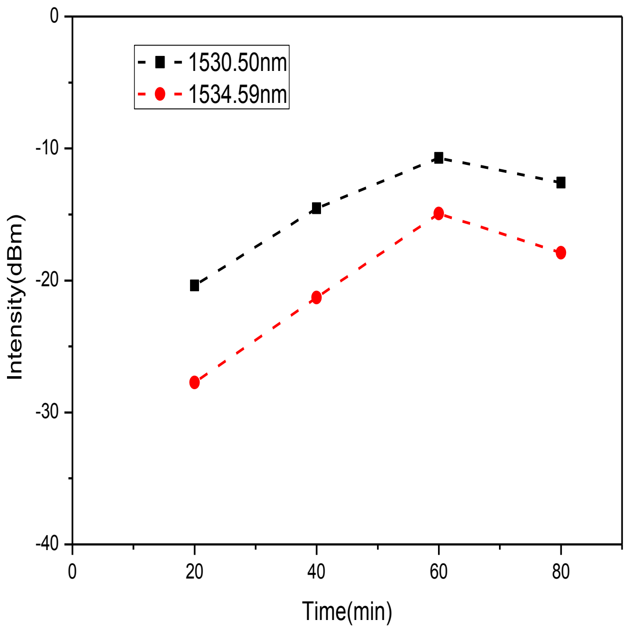

Fig. 5. Stabilities of peak power in the Fig. 3(c) (color online)

Fig. 5 shows the peak-power stabilities of two lasing lines in Fig. 3(c) across time. The maximum peak-power differences of the 1530.50nm and 1534.59nm lasing lines during the 60 minutes are 10 dB and 13 dB, respectively. The factors inducing the instabilities are the power fluctuation of pump source and the intensive mode competition causing by the homogeneous broadening medium EDF.

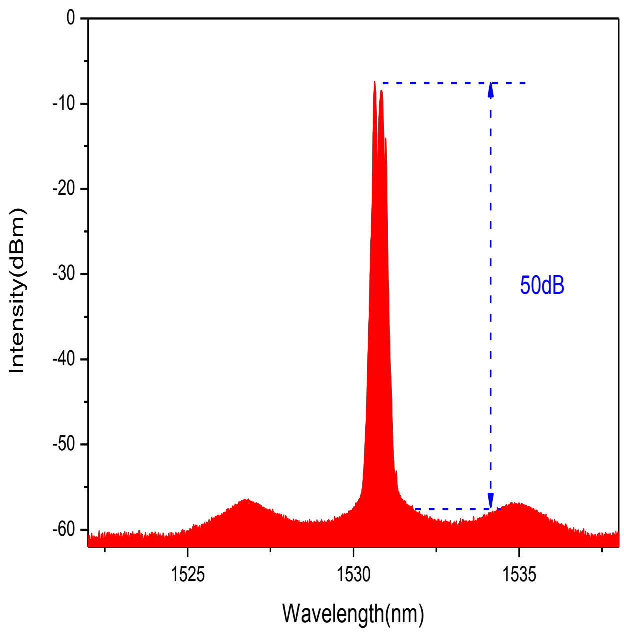

Fig. 6. Single-wavelength output spectrum (color online)

Finally, after the PC was adjusted slowly, this laser could also emit a single-wavelength lasing line as shown in Fig. 6. The lasing line with the OSNR of 50 dB and the 3 dB linewidth of 0.62 nm locates at 1530.76 nm. It can be seen that peak summit appears two small peaks. It shows that the influence of the PSFG is obvious.

4. Conclusion

An SDW-EDFL employing a linear cavity structure are proposed and experimentally demonstrated. Two Sagnac loops including a PSFG and a length of PMF are jointly used to excite multiple wavelengths output. Under the role of the PHB effect, the laser realizes six kinds of diff erent lasing lines, which could be switched freely one another.

Acknowledgments

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