

Wavelength-switchable operation of quadruple-wavelength EDF laser

JIANQUN CHENG*, YUSHAN LIN

School of Physics and Optoelectronic Engineering, Foshan University, Foshan 528000, China

A wavelength-switchable quadruple-wavelength erbium-doped fiber laser using linear-cavity configuration is proposed and demonstrated experimentally at room temperature. A Sagnac loop with a length of polarization-maintaining fiber acts as a comb filter and a broadband chirped fiber grating with low reflectivity acts as the flat reflective mirror in the resonant cavity. On the basis of the polarization hole burning effect, after adjusting a polarization controller, the laser can switch flexibly to output six different modes from single-wavelength to quadruple-wavelength. All of lasing lines with narrow linewidth of less than 0.3 nm have the optical signal-to-noise ratio of more than 30 dB.

(Received December 5, 2017; accepted April 8, 2019)

Keywords: Erbium-doped fiber laser, Switching, Chirped fiber grating

1. Introduction

The multi-wavelength fiber lasers (MWFLs) at 1.5-micron waveband have been focused on for the application of many important fields, for example, dense wavelength division multiplexing (DWDM) optical communication systems, optical fiber sensors systems, etc.

In recent years, a 14-line multi-wavelength fiber laser with hybrid gain medium (SOA plus erbium-doped fiber (EDF)) was reported by using an in-line quasi-Sagnac interferometer based comb filter [1].

For using EDF as gain medium, simultaneous lasing at up to eight wavelengths was demonstrated in a multi-wavelength EDF ring laser by introducing a feedback fiber loop [2]. An all-fiber passively multi-wavelength Q-switched EDF laser based on a short Carbon Nanotube based saturable absorber was demonstrated [3].

For obtaining wavelength-switchable output, multi-wavelength fiber lasers based on few-mode fiber filter with core-offset structure [4], or by using a fixed fiber-comb filter and a broadband tunable S-bent fiber filter [5], or incorporating all-fibre Fabry-Perot interferometer [6], or based on Mach-Zehnder interferometer and tunable filter [7], or employing seven-core fiber [8] were proposed.

For obtaining tunable multi-wavelength output, different schemes were proposed, such as using graphene thin film as nonlinear medium and stabilizer [9], or optical add-drop multiplexers and a photonic crystal fiber Sagnac interferometer [10], or tunable comb filter and intensity-dependent loss modulation [11], or a double Sagnac comb filter with polarization-maintaining fibers [12], or PM-FBG and Mach-Zehnder interferometer with

optical fiber delay line [13].

In this letter, a switchable quadruple-wavelength EDF laser using a simple linear-cavity configuration is proposed and demonstrated experimentally at room temperature. A Sagnac loop is used as wavelength-selective comb filter to excite multiple wavelength output. A broadband chirped fiber grating (CFG) is used as cavity mirror. Six kinds of different lasing output modes can be obtained and can switch one another.

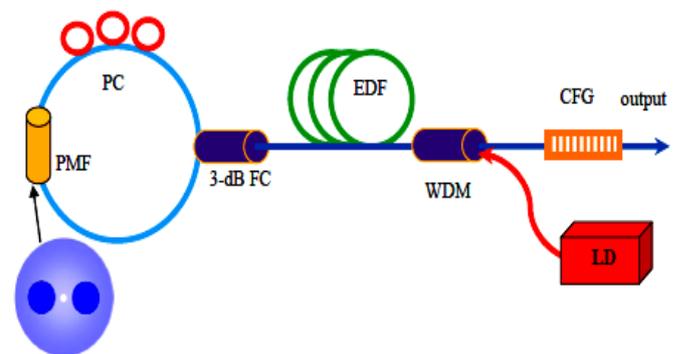


Fig. 1. Configuration diagram of the laser

2. Experiment

The configuration of the proposed switchable quadruple-wavelength EDF laser is shown in Fig. 1. The laser uses a backward pump scheme employing a simple linear cavity structure that consists of a Sagnac loop and a CFG. The left loop with a three-loop type of fiber polarization controller (PC) and a segment of

polarization-maintaining fiber (PMF) is formed by splicing two arms of a 3-dB fiber coupler (FC) with the power ratio of 50 to 50. The PMF with panda-type structure (shown in Fig. 1) has the cut-off wavelength of 1290 to 1520 nm.

A single-mode (SM) laser diode (LD) with the maximum power of 460-mW and the 980-nm central wavelength is used as pump source of the laser. Pump light is coupled in the resonant cavity to pump a length of single-clad, SM, highly-doped EDF through a 980 and 1550-nm wavelength division multiplexing (WDM) coupler. This EDF is manufactured by Fibercore Limited Company and is the I-25 product in the IsoGain™ range. Its absorption coefficient at 980 nm is 27 dB per meter, which is much higher than the value (about 3 dB per meter) of ordinary EDF.

In the experiment, the CFG with low reflectivity is used as flat reflective mirror and has wider reflection spectrum than the ordinary fiber Bragg grating. The CFG is designed to obtain the bandwidth of 10 nm in which more lasing lines caused by the Sagnac loop are permitted to resonate. This experimental principle and result are entirely different with the experiment of the literature [14].

3. Results and discussion

The PC is used to change the polarization state of transmission light in the resonant cavity and continually

adjust birefringence of the PMF in the left loop. Thus a polarization-dependent loss can generate and the polarization hole burning (PHB) effect is induced. Finally, the laser can balance gain and loss of different wavelengths and attain to control the number of the lasing lines.

In the experiment, at the 380-mw pump power, after carefully adjusting the PC, laser light tapping from the right port of CFG is measured by an optical spectrum analyzer (OSA) with a minimum resolution of 0.05 nm. Finally, the laser shows six kinds of different lasing output modes that can switch one another and are shown in Figs. 2 - 6.

At the meantime, the stabilities of peak power and wavelength in lasing lines are measured.

Five-times repeated scan spectra of quadruple-wavelength output are shown in Fig. 2. Four lasing lines with optical signal-to-noise ratio (OSNR) of more than 30 dB and 3-dB linewidth of 0.19 nm are measured to locate in the 1556.1 nm, 1557.3 nm, 1558.6 nm and 1559.8 nm, respectively. The adjacent line space is uniform and about 1nm. It can be measured that maximum difference of peak power in them is 6 dB, which shows that the laser has better power uniformity. It can be seen from Fig. 2 that the wavelength stability of the four lines is very good and no obvious wavelength shift happens in 25 min.

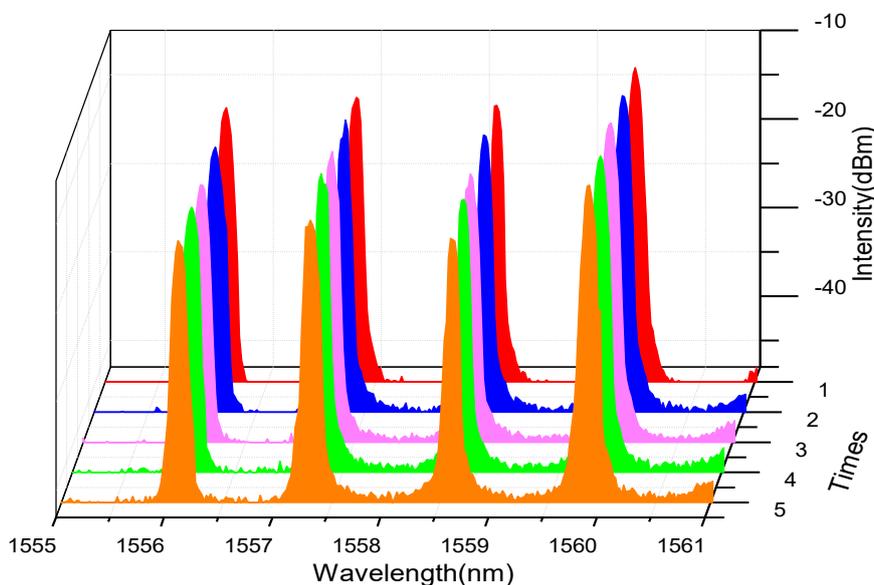


Fig. 2. Five-times repeated scan spectra of quadruple-wavelength output

Stability of quadruple-wavelength peak power with time is measured in the experiment. The result is shown in Fig. 3. Among the four lines, maximum peak-power shift

at 1556.1 nm attains to 2 dB and minimum peak-power shift at 1559.8 nm is only 0.6 dB over 25 min.

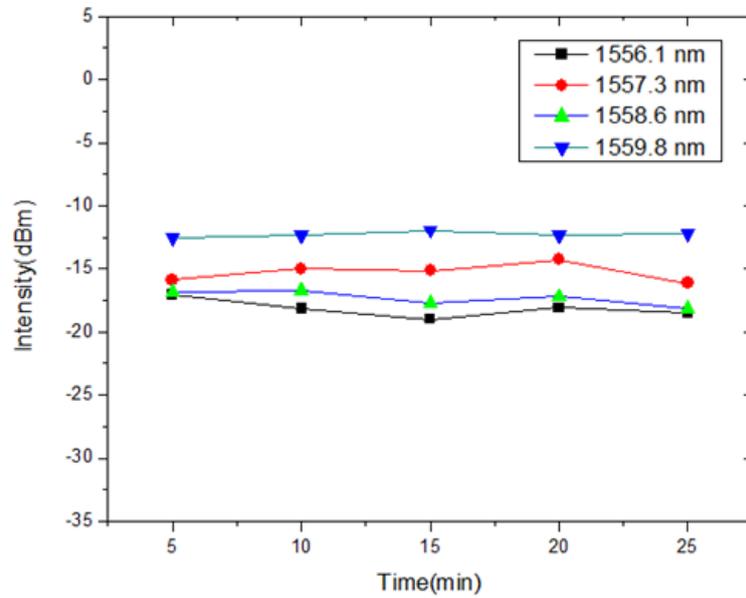


Fig. 3. Stability measurement of quadruple-wavelength peak power

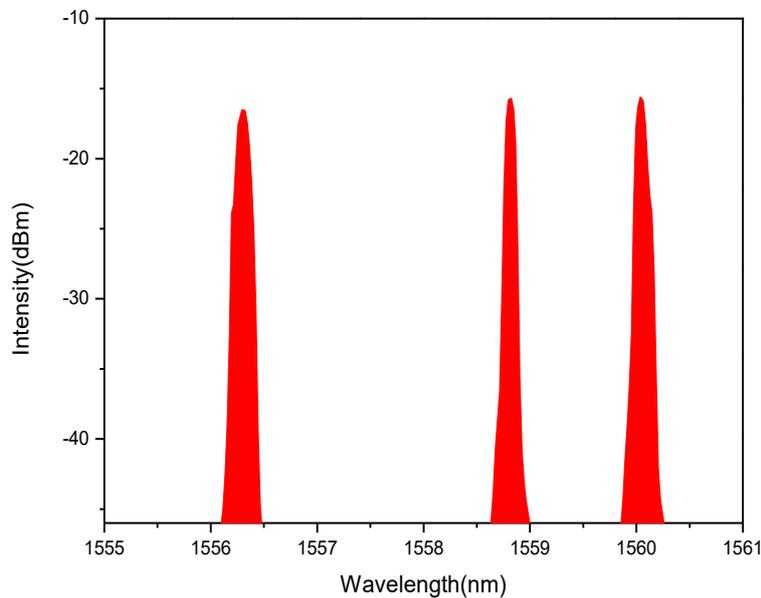


Fig. 4. Output spectra of triple-wavelength

After the PC is further adjusted the polarization states of transmission light, one of the lasing lines is very well compressed in the resonant cavity. This laser has one kind of triple-wavelength output mode shown in Fig. 4. Three lasing lines of triple-wavelength locate in the 1556.3 nm, 1558.8 nm and 1560.0 nm in turn and have peak-power difference of 1 dB. The three lasing lines have 3-dB

linewidth of less than 0.2 nm and the OSNR of more than 34 dB.

This laser also has two kinds of dual-wavelength output modes shown in Fig. 5. Among them, two lasing lines of dual-wavelength (a) locate respectively in the 1555.9 nm and 1557.1 nm and have no peak-power difference. Two lasing lines of dual-wavelength (b) locate

respectively in the 1556.2 nm and 1559.9 nm and have peak-power difference of 1.6 dB. All of dual-wavelength lasing lines have 3-dB linewidth of less than 0.3 nm and the OSNR of more than 31 dB.

Two kinds of single-wavelength output modes can be obtained and are shown in Fig. 6. This lasing line of

single-wavelength (c) with the central wavelength of 1556.3 nm and 3-dB linewidth of 0.2 nm has the OSNR of more than 32 dB. Meanwhile, this lasing line of single-wavelength (d) with the central wavelength of 1557.0 nm and 3-dB linewidth of 0.2 nm has the OSNR of more than 38 dB.

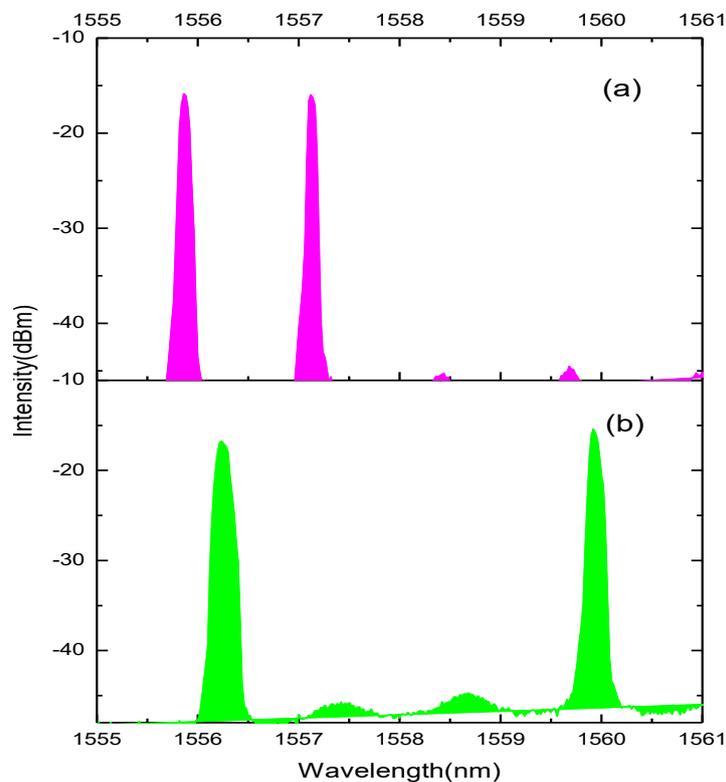


Fig. 5. Output spectra of switchable dual-wavelength

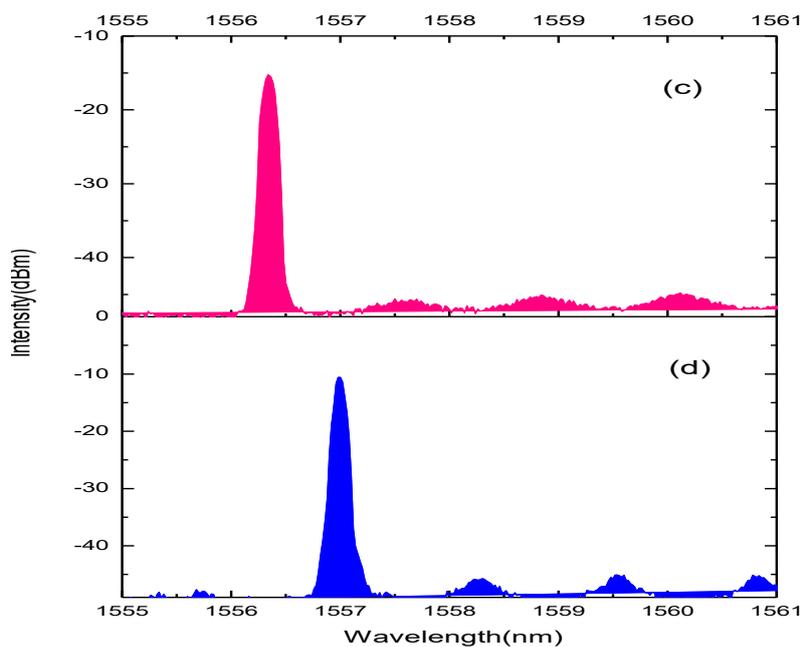


Fig. 6. Switchable single-wavelength output spectra

4. Conclusion

A novel wavelength-switchable quadruple-wavelength erbium-doped fiber laser with a Sagnac loop mirror and a CFG is demonstrated at room temperature. The PMF-based Sagnac loop acts as a comb filter and the CFG with low reflectivity acts as a flat reflective mirror. By using PHB effect, the laser can switch flexibly to output six kinds of different lasing modes with good stability with respect to the peak power and wavelength.

Acknowledgment

This work is supported by the <Special Funds for the Cultivation of Guangdong College Students' Scientific and Technological Innovation ("Climbing Program" Special Funds)> under Grant < number pdjh2016b0525>.

References

- [1] H. Sun, J. Zhang, Z. H. Yang, L. B. Zhou, X. G. Qiao, M. L. Hua, *Opt. Laser Technol.* **72**, 65 (2015).
- [2] S. Diaz, M. Lopez-Amo, *Opt. Laser Technol.* **78**, 134 (2016).
- [3] B. Dong, J. H. Hu, C. Y. Yu, J. Z. Hao, *Opt. Commun.* **285**, 3864 (2012).
- [4] Y. H. Qi, Z. X. Kang, J. Sun, L. Ma, W. X. Jin, Y. D. Lian, S. S. Jian, *Opt. Laser Technol.* **81**, 26 (2016).
- [5] A. Martinez-Rios, G Anzueto-Sanchez, D. Monzon-Hernandez, G Salceda-Delgado, J. Castrellon-Uribe, *Opt. Laser Technol.* **58**, 197 (2014).
- [6] W. He, L. Q. Zhu, M. L. Dong, X. P. Lou, F. Luo, J. *Mod. Optic.* **65**, 7 (2018).
- [7] W. He, L. Q. Zhu, M. L. Dong, X. P. Lou, F. Luo, *Laser Phys.* **28**, 4 (2018).
- [8] W. He, W. Zhang, L. Q. Zhu, X. P. Lou, M. L. Dong, *Opt. Fiber Technol.* **46**, 30 (2018).
- [9] H. Ahmad, N. A. Hassan, S. N. Aidit, Z. C. Tiu, *Opt. Laser Technol.* **81**, 67 (2016).
- [10] S. Rota-Rodrigo, R. A. Perez-Herrera, I. Ibanez, A. M. R. Pinto, M. Fernandez-Vallejo, M. Lopez-Amo, *Opt. Laser Technol.* **48**, 72 (2013).
- [11] M. R. Quan, Y. Li, J. J. Tian, Y. Yao, *Opt. Commun.* **340**, 63 (2015).
- [12] W. He, C. M. Shangguan, L. Q. Zhu, M. L. Dong, Fei Luo, *Optik* **137**, 254 (2017).
- [13] W. He, D. Li, L. Q. Zhu, M. L. Dong, F. Luo, *IEEE Photonics J.* **9**, 3 (2017).
- [14] J. Q. Cheng, W. C. Chen, G. J. Chen, *Opt. Laser Technol.* **78**, 71 (2016).

*Corresponding author: cheng.jq@qq.com