

# A method of narrow the optical line-width of the fiber laser

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A method with a simple configuration is demonstrated to narrow the spectrum line-width of the fiber lasers. The configuration consists of one coupler and four fiber Bragg gratings (FBGs). The number of longitudinal modes is decreased significantly using multi-cavities by comparing multi-cavities configuration with single-cavity configuration. The spectrum line-width is effectively narrowed. The whole system is simple in technology and low in cost.

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In recent years, narrow spectrum line-width erbium-doped fiber (EDF) lasers have been researched widely, because of its potential applications in optical communications, fiber sensors, and spectroscopy. The advantage of unidirectional ring-cavity configuration is its high output power with low relative intensity noise<sup>[1,2]</sup>. However, ring-cavity configuration fiber lasers, generally, have relatively long cavity lengths, which have to bring out an enormous number of densely spaced longitudinal modes lying beneath the erbium gain curve. In order to increase the space of adjacent longitudinal modes, short linear cavities have become the first candidate of the cavity structure for fiber lasers. However, the cavities must be short enough, a traditional single longitudinal mode short cavity fiber laser typically needs a cavity of several centimeters, to enable the space of longitudinal modes can be comparable with the bandwidth of the filters, while the laser output power is limited.

Various filters are necessary for fiber lasers, such as fiber Bragg gratings (FBGs), Sagnac loop, saturated absorber, etc. FBGs have the advantages such as wavelength-selective nature, fiber compatibility, ease of use and fabrication, and low cost<sup>[3–8]</sup>. Even a single FBG also provides excellent performance for a distributed feedback (DFB) fiber laser<sup>[9–13]</sup>.

In this letter, we present a simple configuration to narrow the spectrum line-width of the fiber laser with multi-cavities. The number of longitudinal modes is decreased effectively using multi-cavities by comparing multi-cavities configuration with single-cavity configuration. The laser configuration proposed can decrease the number of longitudinal modes effectively.

A simple multi-cavities configuration is shown in Fig. 1. To narrow the spectrum line-width, a 50:50 fiber coupler and four FBGs are used in the laser configuration. The four FBGs are fabricated under the same condition by using the same phase mask and KrF pulse laser. And all of them are almost identical at the wavelengths (FBG1: 1544.535 nm, FBG2: 1544.524 nm, FBG3: 1544.576 nm, and FBG4: 1544.540 nm) and the reflectivities (FBG1: 96.02%, FBG2: 95.53%, FBG3: 96.45%, FBG4: 95.63%) as shown in Fig. 2.

The length of the EDF is about 4.4 m and the length of each tail of the coupler is about 1 m as shown in

Fig. 1. The fiber laser is pumped by a laser diode (LD) with the center wavelength of 980 nm. To improve the longitudinal modes discrimination, a coupler is set up in the proposed configuration. The spectral characteristics are measured by using an ANDO AQ6317 optical spectrum analyzer (OSA) with 0.01-nm resolution. The output is injected into a 10-GHz photodetector (PD), and then monitored the electrical beating signal through an electrical spectrum analyzer (ESA) (N9010A|Agilent, 9 kHz–26.5 GHz).

The laser output measured by the OSA is shown in Fig. 3. As shown in Fig. 3(a), the lasing wavelength is 1544.529 nm, and the full-width at half-maximum (FWHM) is 0.013 nm. Because the minimum resolution of the OSA is 0.01 nm, the last number is not exact but with the error of no more than 0.01 nm. Figure 3(b) shows the optical spectrum of the laser output measured in the wavelength range from 1500 to 1600 nm. It can be seen from 15 times repeated sweeps for 7 minutes by the OSA as shown in Fig. 3(c) that the stability of the laser output from the multi-cavities fiber laser is satisfactory. The stability of the proposed fiber laser can be improved by adopting the special grating packaging technologies

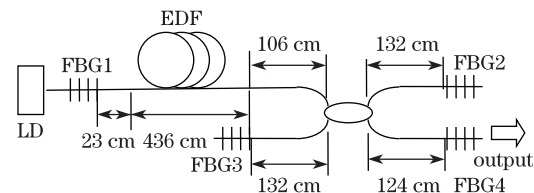


Fig. 1. Experimental configuration of the proposed multi-cavities fiber laser.

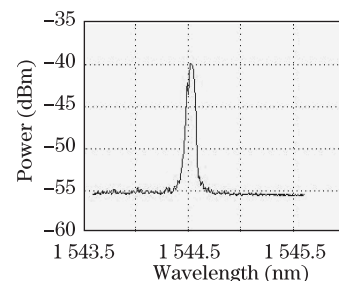


Fig. 2. Reflectance spectrum of FBG1 for instance.

and temperature controlling technologies.

The laser output power as a function of the pump power is shown in Fig. 4. When the pump power is 103 mW, the output power is 575  $\mu$ W. The threshold is 35 mW, and the slope efficiency is 0.558%. The slope efficiency could be improved by decreasing the reflectivity of FBG4 but increasing the reflectivities of the other three FBGs.

Then we inject the laser output into the PD, and detect the electrical signal from the PD by using the ESA. Figure 5(a) shows the electrical beating signals measured

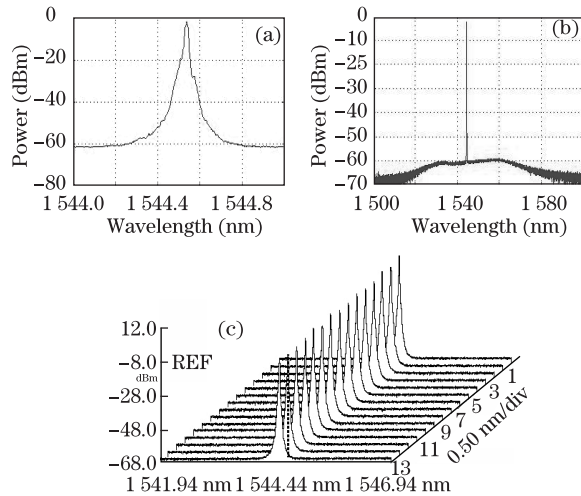


Fig. 3. Output spectrum of multi-cavities fiber laser. (a) Single sweep from 1544 to 1545 nm; (b) single sweep from 1500 to 1600 nm; (c) 15 times repeated sweeps for 7 minutes.

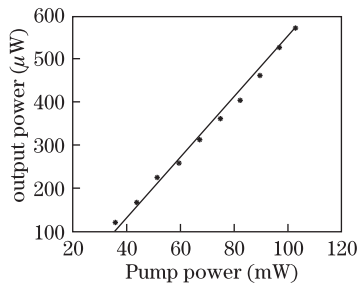


Fig. 4. Laser output power as a function of the pump power.

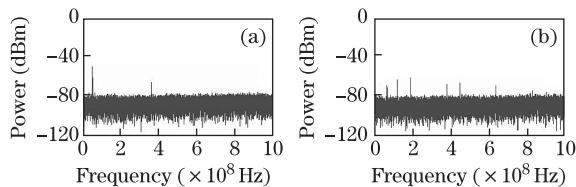


Fig. 5. Configuration of linear cavity without coupler.

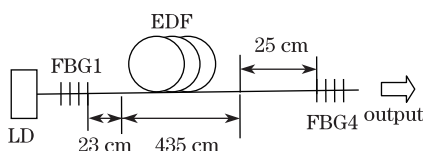


Fig. 6. Frequency spectrogram (a) with and (b) without coupler.

by the ESA, which indicates that the multi-cavities fiber laser operates in few longitudinal modes oscillation. In order to verify the modes controlling effect, we remove the coupler from the configuration and splice the FBG4 with the EDF directly as shown in Fig. 6. When the pump power is 103 mW, the output power is 1.66 mW. The electrical beating signals is measured again, and the result is shown in Fig. 6(b) which presents the fiber laser operates in multi-mode oscillation with a strong beating noise caused by mode beating. Comparing Fig. 6(a) with Fig. 6(b), we can firmly believe that the laser configuration proposed can decrease the number of longitudinal modes effectively.

In conclusion, we propose and experimentally demonstrate a multi-cavities fiber laser using a fiber coupler and four FBGs. The number of longitudinal modes is decreased significantly using multi-cavities by comparing multi-cavities configuration with single-cavity configuration. So the spectrum line-width of the multi-cavities fiber laser is narrower than that of the single-cavity one. The stability of the proposed fiber laser can be improved by adopting the special grating packaging technologies and temperature controlling technologies, and it could be expected that the performance is improved by adding extra couplers and FBGs, or by varying the length of each cavity. The whole laser system is simple in structure and low in cost.

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## References

1. N. Park, J. W. Dawson, K. J. Vahala, and C. Miller, *Appl. Phys. Lett.* **59**, 2369 (1991).
2. A. Gloag, N. Langford, K. McCallion, and W. Johnstone, *J. Opt. Soc. Am. B* **13**, 921 (1996).
3. C. R. Giles, *Lightwave Technol.* **15**, 1391 (1997).
4. R. Slavik, S. Doucet, and S. LaRochelle, *Lightwave Technol.* **21**, 1059 (2003).
5. R. Gafsi, *Opt. Fiber Technol.* **6**, 299 (2000).
6. K. O. Hill and G. Meltz, *Lightwave Technol.* **15**, 1263 (1997).
7. K. O. Hill, B. Malo, F. Bilodeau, D. C. Johnson, and J. Albert, *Appl. Phys. Lett.* **62**, 1035 (1993).
8. S. V. Chernikov, J. R. Taylor, and R. Kashyap, *Opt. Lett.* **18**, 2023 (1993).
9. J. Hubner, P. Varming, and M. Kristensen, *Electron. Lett.* **33**, 139 (1997).
10. M. Ibsen, A. Shaif-ul, M. N. Zervas, A. B. Grudinin, and D. N. Payne, *Photon. Technol. Lett. IEEE* **11**, 1114 (1999).
11. S. Yamashita and G. J. Cowle, *Lightwave Technol. J.* **17**, 509 (1999).
12. M. Ibsen, E. Ronnekleiv, G. J. Cowle, M. N. Zervas, and R. I. Laming, *Electron. Lett.* **36**, 143 (2000).
13. S. Jie, D. Yitang, C. Xiangfei, Z. Yejin, and X. Shizhong, *Photon. Technol. Lett. IEEE* **18**, 2587 (2006).