Multiwavelength erbium fiber ring laser using Sagnac loop and Fabry-Perot laser diode

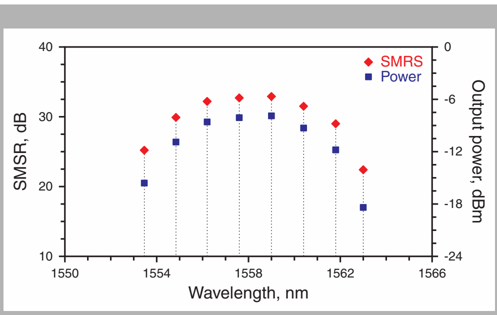
2008 Laser Phys. Lett. 5 210

(http://iopscience.iop.org/1612-202X/5/3/009)

Laser Physics
Letters

Laser Phys. Lett. **5**, No. 3, 210–212 (2008) / **DOI** 10.1002/lapl.200710113

Abstract: We propose and demonstrate experimentally a simply multiple-wavelength erbium compound ring fiber laser employing a Sagnac interferometer with erbium-doped fiber amplifier (EDFA) and Fabry-Perot laser diode (FP-LD). The proposed laser has the advantage of simply structure and easy fabrication, lower insertion loss and cost-effective. Based on the Sagnac fiber laser scheme, the proposed laser can lase eight wavelengths simultaneously. Moreover, the optical output stability of the ring laser has been also discussed.



Side-mode suppression ratios and output powers of the lasing multiple-wavelength

Multiwavelength erbium fiber ring laser using Sagnac loop and Fabry-Perot laser diode

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Received: 9 November 2007, Revised: 12 November 2007, Accepted: 15 November 2007

Key words: ring laser; multiple-wavelength; Sagnac loop

PACS: 42.60.Da, 42.81.-i, 42.81.Wg

1. Introduction

Wavelength-division-multiplexing (WDM) transmission is a very important technology in optical fiber communication while it is an economical and efficient way increasing the data capacities. Wavelength-tunable and single-frequency fiber ring lasers were hugely discussed in the past for the application of optical communications [1–4]. Besides, it is always desirable having the multiwavelength fiber lasers in a WDM transmission system. One way to generate multi-lightwave was to employ a comb filter, whose spectral response was intensity modulated periodically in wavelength. It was the most attractive scheme since it finds rather easy to define the lasing wavelengths [5]. However, the effectively operating bandwidth of fiber lasers depends on the amplification range of optical amplifier, such as S-, C-, and L-bands [6,7]. With the development of fabrication technique of optical fiber grating, a number of all-fiber comb filters based on fiber gratings have been presented. They include sampled Bragg grating, highbirefringence fiber loop mirror, cascaded long period gratings wide-band chirped grating Fabry–Perot (FP) resonator and fiber Bragg grating Michelson interferometer [8–13]. For most of those that consist of grating pairs, two identical fiber gratings are demanded, otherwise undesired characteristics may happen. Thus, to fabricate such filters, careful and complex control techniques are required. Besides, an all-fiber comb filter based on a Sagnac interferometer, with a fiber Bragg grating (FBG) asymmetrically located, inside a fiber loop for lasing multiple-wavelength has also reported [14–17].

In this paper, we have proposed and investigated a novel and simple configuration for the multiple-wavelength fiber ring laser based on Sagnac ring loop and

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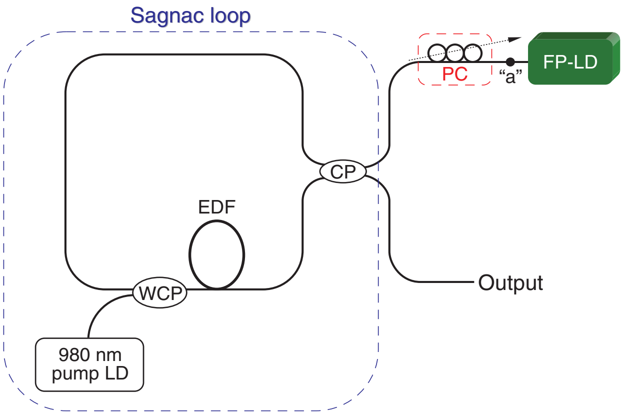

Figure 1 (online color at www.lphys.org) Experimental setup of the proposed multiple-wavelength fiber laser. LD – laser diode, PC – polarization controller, EDF – erbium-doped fiber, CP – 2×2 optical coupler, WCP – 980/1550 nm WDM coupler, EDFA – erbium-doped fiber amplifier, FP-LD – Fabry-Perot laser diode

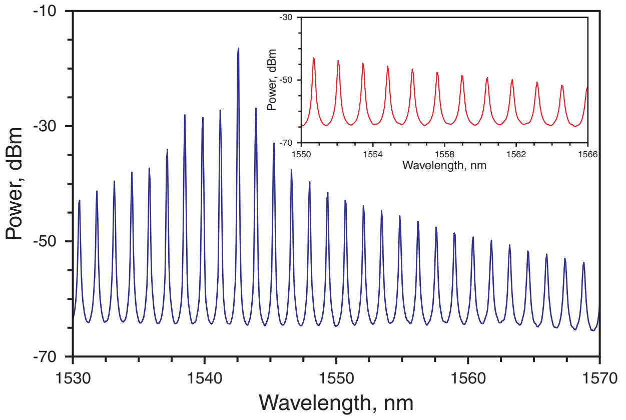

Figure 2 (online color at www.lphys.org) Output spectrum of the FP-LD which is observed at "a" point in the wavelengths of 1530 to 1570 nm when the bias current and temperature are 13 mA and 23°C. The insert also shows the same spectrum in the wavelengths of 1550 to 1566 nm

FP-LD. Furthermore, in contrast with the past study; the proposed laser scheme is easy to be constructed and has low cost. In addition, the performance of the output stability for the multi-wavelength fiber laser operated at optimal driving condition has been also discussed.

2. Experiments and results

An experimental setup of the proposed multi-wavelength fiber laser is illustrated in Fig. 1. The proposed fiber laser is consisted of a Sagnac ring loop, a polarization controller (PC) and a FP-LD. The Sagnac loop is constructed by an erbium-doped fiber amplifier (EDFA) and a 2×2 and 50:50 optical coupler (CP). The EDFA is manufactured by an EDF with 10 m long, a 980/1550 nm WDM coupler (WCP), an optical isolator (OIS) and a 980 nm pumping laser with 60 mW. The proposed Sagnac fiber loop has a 14.5 m long. Therefore, using the optimal cavity lengths of Sagnac loop, the multi-wavelength can be lased for the proposed laser without any optical filter inside ring cavity. The polarization controller is used to control the intracavity polarization state from FP-LD to the Sagnac interferometer. Moreover, the output power and wavelength of the fiber laser are measured by an optical spectrum analyzer (OSA) with a 0.05 nm resolution.

Fig. 2 shows the output spectrum of the FP-LD which observes at "a" point (as shown in Fig. 1) in the wavelengths of 1530 to 1570 nm when the bias current and temperature are 13 mA and 23 °C. The insert of Fig. 2 also shows the same spectrum in the wavelengths of 1550 to 1566 nm and the noise background is around – 64 dBm. The lasing modes at 1553.44, 1554.82, 1556.2, 1557.58, 1558.96, 1560.4, 1561.78, and 1563.16 nm have the output power levels between – 44.68 and – 50.64 dBm. Beside, the central wavelength and mode spacing of FP-LF is 1542.58 and 1.38 nm, respectively. In the proposed laser, since the proposed Sagnac cavity loop is polarization-dependent, the output power can be adjusted by varying the eigenstate of the polarization inside ring. Furthermore, by adjusting the PC to align the maximum output power of eigenstate of the polarization can always be retrieved. The proposed fiber laser will lase multi-wavelength because of the simply laser architecture. As a pumping power of 980 nm LD increases to 60 mW, the multi-wavelength spectrum of fiber laser can lase eight continuous wavelengths simultaneously, as shown in Fig. 3a. The lasing eight wavelengths of the multi-wavelength laser are 1553.4 (λ_1), 1554.8 (λ_2), 1556.2 (λ_3), 1557.6 (λ_4), 1559.0 (λ_5), 1560.4 (λ_6), 1561.8 (λ_7), and 1563.1 nm (λ_8), respectively. The mode spacing ($\Delta\lambda$) of the multiple-wavelength laser is nearly 1.4 nm and the maximum difference side-mode suppression ratio (SMSR) of the eight wavelength is about 10 dB. According to Fig. 2 and Fig. 3a, the other side-mode of FP-LD could be suppressed due to the Sagnac interferometer. In accordance with the operating principle of the laser, thus the maximum gain distribution was around 1560 nm. Therefore, the proposed laser could lase the eight wavelengths between 1553.4 and 1563.1 nm. Fig. 3b presents that the side-mode suppression ratios (SMSRs) and output powers of the lasing multi-wavelength are 25.2, 29.9, 32.2, 32.7, 32.9, 31.5, 29, and 22.4 dB, and – 15.6, – 10.9, – 8.6, – 8.1, – 7.9, – 9.3, – 11.8, and – 18.4 dBm, respectively. The maximum power and SMSR differences between 1556.2 and 1560.4 nm are 1.4 dB. Besides, the laser can also be selected in various operating range by using the Sagnac interferometer with different loop length. Comparisons of the multiwavelength fiber lasers with the past studies [8–17], the proposed multiwavelength fiber laser not only has simple laser scheme but also has the lower pumping power of 980 nm

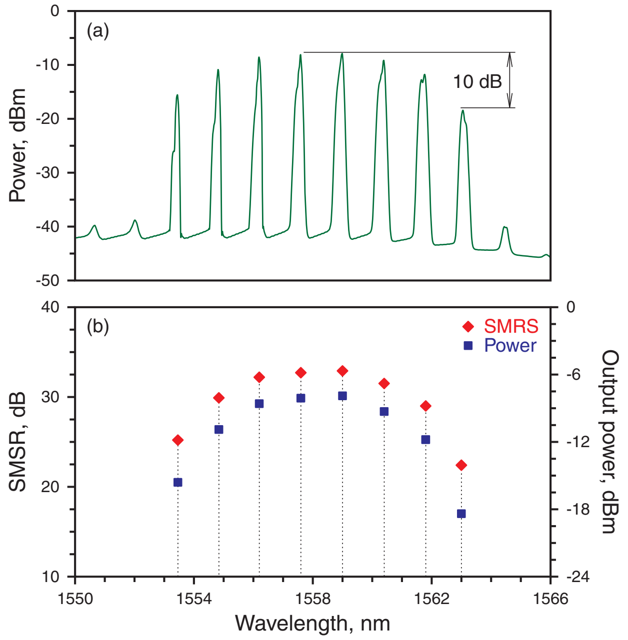

Figure 3 (online color at www.lphys.org) (a) The multi-wavelength spectra of the proposed fiber laser at 1553.4, 1554.8, 1556.2, 1557.6, 1559.0, 1560.4, 1561.8, and 1563.1 nm, respectively. (b) Side-mode suppression ratios and output powers of the lasing multiple-wavelength

LD and bias current of FP-LD. The past technology used high power nonlinear effect or complex scheme.

To verify the performances of output power and output wavelength stabilities, a short-term stability for the triple-wavelength laser is measured and shown in Fig. 4. The lasing eight wavelengths are observed time in 20 minutes and the observing wavelength variation is zero. Over the observing time, the output power fluctuations of the eight wavelengths are 0.18, 0.25, 0.09, 0.1, 0.15, 0.1, 0.16, and 022 dB, respectively, as also shown in Fig. 4. In an hour observation, the stabilized output of the ring laser is still maintained. As a result, the proposed ring laser has the advantage of simply architecture, low cost and stable wavelength output.

3. Conclusion

In summary, we have proposed and investigated experimentally a simply multiple-wavelength erbium compound ring fiber laser employing a Sagnac interferometer with erbium-doped fiber amplifier and Fabry-Perot laser diode. The proposed laser has the advantage of simply structure and easy fabrication, lower insertion loss and cost-effective. Based on the Sagnac fiber laser scheme, the proposed laser can lase eight wavelengths simultaneously, which are 1553.4, 1554.8, 1556.2, 1557.6, 1559.0, 1560.4, 1561.8, and 1563.1 nm, respectively. And the output power and SMSR are larger than – 18.4 dBm and 22.4 dB over the lasing wavelengths. In addition, the optical output stability of the ring laser has been also discussed.

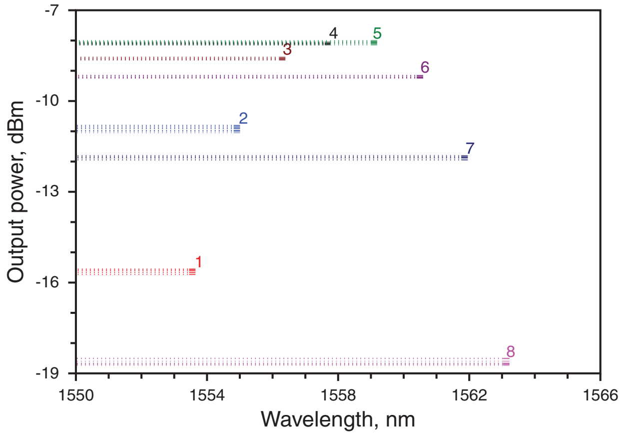

Figure 4 (online color at www.lphys.org) Observing short-term stability of the output power for the proposed laser under the observing time of 20 minutes

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