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Use of a reflective semiconductor optical amplifier and dual-ring architecture design to produce a stable multi-wavelength fiber laser

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Abstract
In this work, we propose and demonstrate a multi-wavelength laser source produced by utilizing a C-band reflective semiconductor optical amplifier (RSOA) with a dual-ring fiber cavity. Here, the laser cavity consists of an RSOA, a 1×2 optical coupler, a 2×2 optical coupler and a polarization controller. As a result, thirteen to eighteen wavelengths around the L band could be generated simultaneously when the bias current of the C-band RSOA was driven at 30–70 mA. In addition, the output stabilities of the power and wavelength are also discussed.

Keywords: fiber lasers, fiber optics, communication optical

(Some figures may appear in colour only in the online journal)

1. Introduction

Nowadays,multi-wavelength fiber-optic lasers are essential for many different applications of fiber communication systems: in optical testing, fiber sensors, radio-frequency photonics [1–4], etc. Moreover, several fiber laser resonators for multi-wavelength lasing use have been proposed and studied: the Fox–Smith cavity, linear cavity, dual Sagnac loop, ring cavity, compound-ring cavity [5–9], etc.

Furthermore, there have been studies of methods involving the use of several different gain media in fiber cavities, such as utilizing erbium doped fiber amplifiers (EDFA), semiconductor optical amplifiers (SOA), reflective semiconductor optical amplifiers (RSOA), stimulated Raman scattering, stimulated Brillouin scattering, and reflective semiconductor optical amplifiers (RSOA), and of combinations of these methods [10–15]. However, the SOA and RSOA would be better choices than EDFA due to the nature of the inhomogeneous broadening. Besides this, RSOA-based and SOA-based fiber lasers have been employed to generate multi-wavelength output at room temperature [16–21].

In this investigation, we propose and experimentally demonstrate employing a C-band RSOA with a dual-ring cavity to produce multi-wavelength lasing in the L-band range of 1580.81–1614.34 nm at room temperature. The proposed laser scheme is simple; the construction only requires an RSOA, a polarization controller (PC), and two 3 dB optical couplers. Here, lasing with thirteen to eighteen wavelengths could be measured, while different DC currents in the RSOA were employed. Moreover, we also investigate and analyze

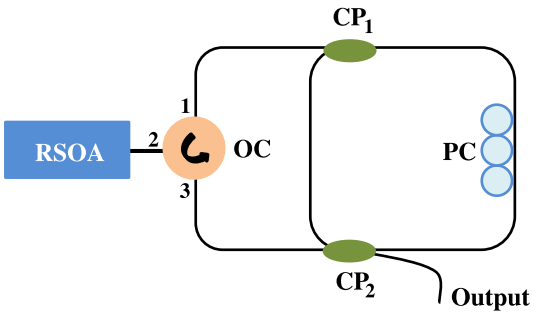

Figure 1. Experimental setup of the proposed multi-wavelength RSOA-based fiber ring laser.

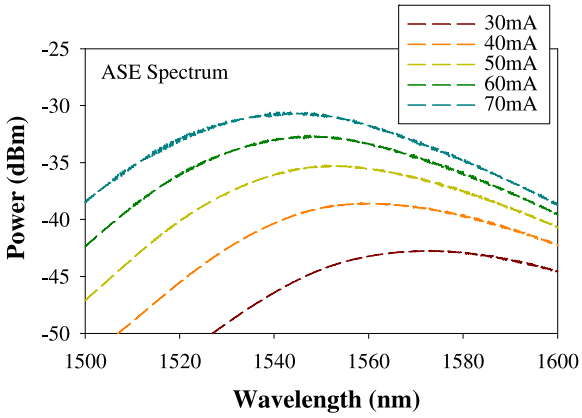

Figure 2. Output ASE spectra of the RSOA under bias currents of 30–70 mA.

the output stabilities of the lasing wavelength and power in the proposed L-band multi-wavelength fiber laser.

2. The experimental setup

The experimental setup of the proposed multi-wavelength fiber laser configuration with the dual-ring cavity scheme is illustrated in figure 1. The proposed fiber laser consists of a C-band RSOA, a PC, a 1 × 2 optical coupler, a 2 × 2 optical coupler and an optical circulator (OC). In the measurement, the RSOA (produced by*CIP*) can be operated at bias currents from 30 to 70 mA. Here, the two couplers could produce the dual-ring cavity for the proposed fiber laser scheme. The OC is utilized to generate a counterclockwise propagation. The PC, which is placed in the ring cavity, is utilized to maintain the polarization state and obtain the maximum output power. Here, the output spectrum could be measured by using an optical spectrum analyzer with a resolution of 0.01 nm.

In the experiment, the characteristic of the RSOA adopted in the design is essential to the performance of the proposed fiber laser, when the multiple wavelengths are generated in the proposed laser scheme. Thus, we measure the output amplified spontaneous emission (ASE) spectra of the RSOA at the operation currents of 30–70 mA. As illustrated in figure 2, on increasing the DC bias current gradually, the output power of the ASE also increases. Moreover, the central wavelength of the ASE also shifts to shorter wavelength, as shown in figure 2. And the gain profile of the RSOA is distributed at the C band in these bias currents [22].

In the proposed RSOA-based dual-ring fiber laser, the multi-wavelength lasing could be measured with appropriate polarization adjustment. Thus, figure 3 shows the measured output optical spectra of the proposed multi-wavelength laser at bias currents from 30 to 70 mA. As shown in figure 3, fourteen wavelengths can be generated simultaneously by using the proposed RSOA-based dual-ring fiber laser, when the optical signal to noise ratio of each wavelength is larger than 20 dB and the RSOA is operated at 30 mA. And the multi-wavelength lasing range is between 1588.48 and 1612.71 nm. Moreover, while the operation current of the RSOA is below 30 mA, there is no lasing wavelength which can be observed. That is to say, the threshold current of the proposed fiber laser is around 30 mA. As shown in figure 3, the lasing wavelength range of the proposed laser is measured as between 1588.48 and 1612.71 nm, 1580.74 and 1613.70 nm, 1584.22 and 1608.37 nm, and 1580.81 and 1614.34 nm, respectively, when the bias current of the RSOA is at 40, 50, 60 and 70 nm.

In the measurement, the maximum peak power of the lasing wavelength is observed at 1592.18, 1593.95, 1593.81, 1604.68 and 1610.65 nm, respectively, when the bias current is 30, 40, 50, 60 and 70 mA. Previous studies showed that for high input power, the SOA showed a peak gain shift toward longer wavelength [23]; therefore the multi-wavelength laser emits in the L-band window rather than the C-band one under the lasing condition at high feedback power. Furthermore, when the bias current of the RSOA increases, the lasing multiple wavelength shifts to longer wavelength gradually, and the lasing wavelength range is gradually widened too, as seen in figure 3. Here, the measured mode spacings of the proposed fiber laser under different operation currents are about 1.9 nm. Moreover, with increase of the bias current, the output power and background ASE noise of the proposed fiber laser increase gradually.

Figure 4 presents the number of lasing wavelengths for an optical signal to noise ratio of >20 dB. Here, thirteen to eighteen wavelengths could be obtained under the different bias currents of 30 and 70 mA. In this measurement, we also measure the output power of the proposed fiber laser at bias currents from 30 to 70 mA, as shown in figure 4. The output powers are observed to be between 0.046 and 0.226 mW. Furthermore, the related measured parameters of the proposed fiber ring laser are listed in table 1.

In order to verify the performance as regards output power and wavelength, a short-term stability test of the proposed multi-wavelength laser was performed. In the measurement, the RSOA was set at 70 mA. Hence, figure 5 displays the output spectra of the proposed RSOA-based laser for a short-term observation of 30 min. Here, one of the lasing wavelengths is selected, at 1591.82 nm with peak power −13.9 dBm, in the measurement initially. And the total observing time is over 30 min. As shown in figure 6, output power and lasing wavelength fluctuations of 0.4 dB and 0.07 nm were achieved, respectively, in an observing time of 30 min. Hence, experimental results show that the proposed fiber laser has excellent output stability. In addition, upon

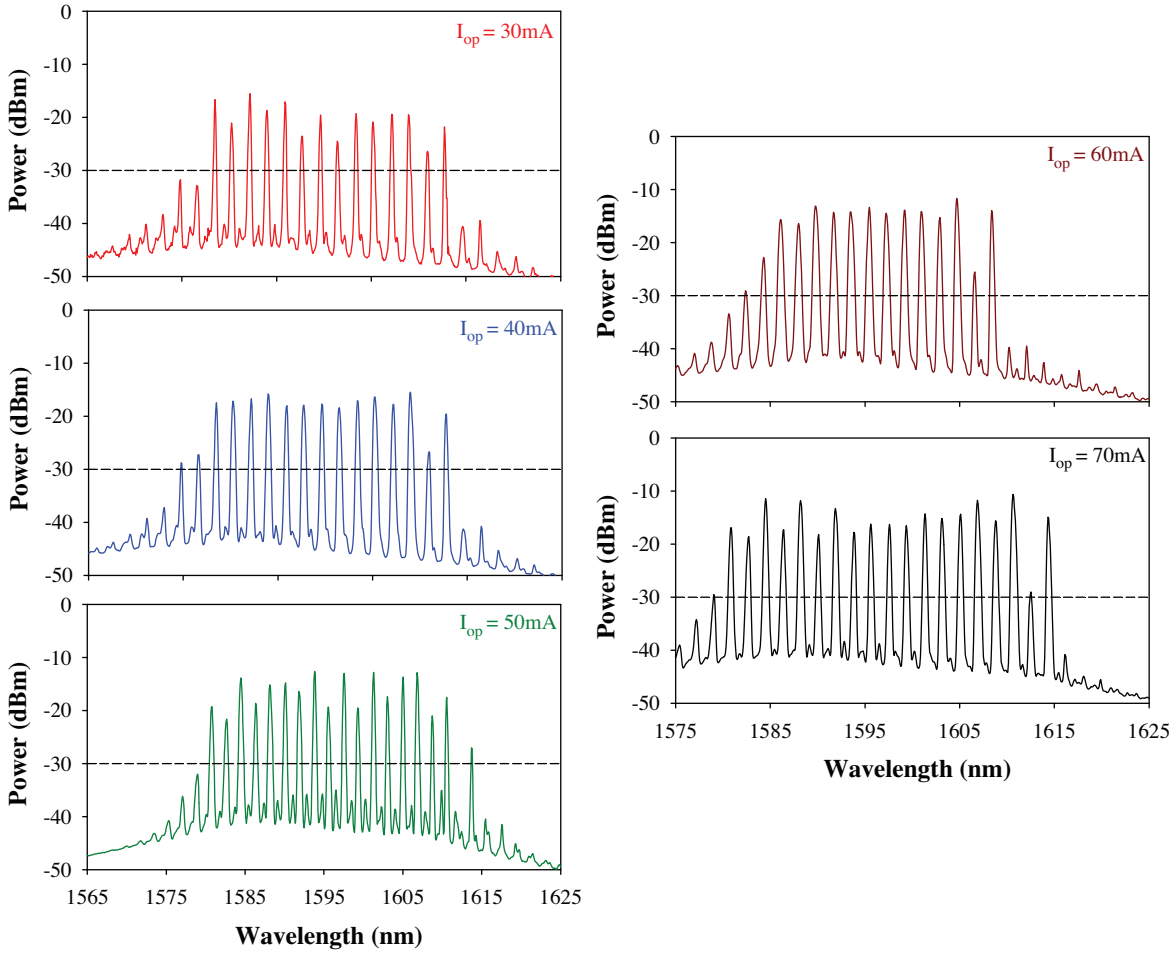

Figure 3. Measured output spectra of the proposed multi-wavelength fiber laser under bias currents of 30–70 mA.

Table 1. The related measured parameters of the proposed RSOA-based fiber laser.

RSOA (mA)	Lasing number	Peak wavelength (nm)	Peak power$_{(max)}$ (dBm)	Output power (mW)	Wavelength range (nm)
30	14	1592.18	−15.5	0.046	1588.48–1612.71
40	13	1593.95	−15.7	0.910	1588.48–1612.71
50	17	1593.81	−12.6	0.137	1580.74–1613.70
60	13	1604.68	−11.7	0.182	1584.22–1608.37
70	18	1610.65	−10.6	0.226	1580.81–1614.34

observing the measurements for an hour, we find that the measured output stabilities of the proposed laser are still maintained.

3. Conclusion

A stable C-band RSOA-based fiber laser with a dual-ring cavity for generating multiple wavelengths in the L-band window at room temperature has been proposed and experimentally demonstrated. Hence, thirteen to eighteen wavelengths for the proposed multi-wavelength lasing can be observed at different bias currents of the RSOA. In this measurement, when the bias current is increased gradually, the output power and the number of lasing wavelengths increase. In addition, the output

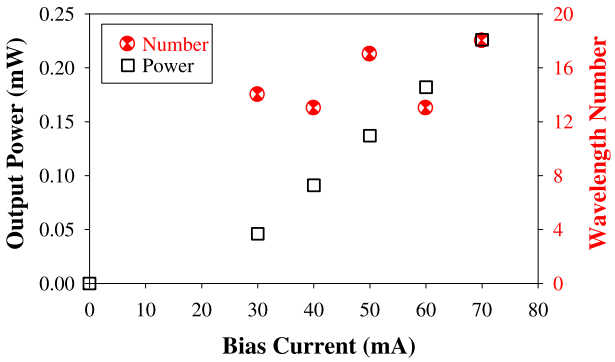

Figure 4. Measured number of lasing wavelengths and total output power of the proposed laser under different bias currents.

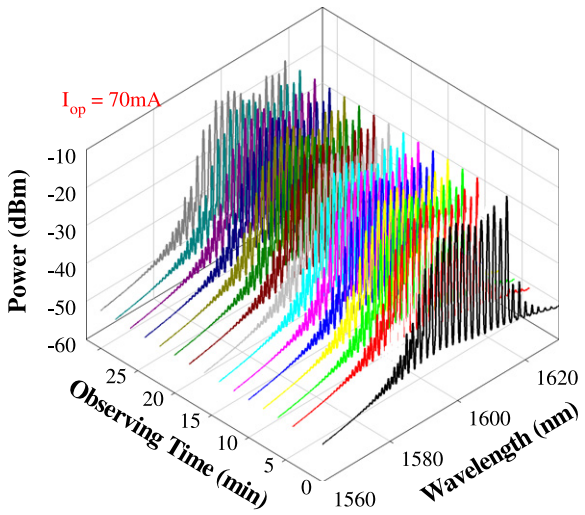

Figure 5. Output spectra of the proposed RSOA-based laser for a short-term observation of 30 min.

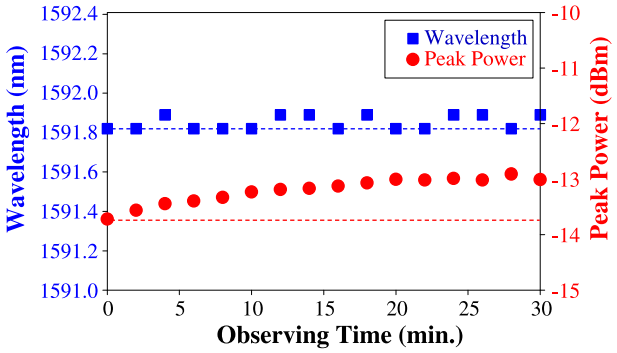

Figure 6. Output wavelength and the power fluctuations of the proposed multi-wavelength fiber laser in an observing time of 30 min, when one of the lasing wavelengths is selected at 1591.82 nm initially.

power fluctuation and lasing wavelength of the proposed fiber laser are measured as 0.4 dB and 0.07 nm, respectively. And during the 1 h observation time, the measured output stabilities of the proposed laser are still maintained.

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