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LETTER

Using a C-band reflective semiconductor optical amplifier and linear cavity laser scheme for L-band multi-wavelength lasing

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Abstract
In this demonstration, we first propose and experimentally investigate an L-band multi-wavelength source only using a C-band reflective semiconductor optical amplifier (RSOA) and a linear cavity formed by a fiber coupler, a polarization controller and a reflected fiber mirror. According to the proposed laser structure, two to seven wavelengths can be generated simultaneously in the L-band when the RSOA is operated at different bias currents. Moreover, the stability performances of output power and lasing wavelength are also discussed.

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

1. Introduction

Recently, multi-wavelength fiber lasers have become very important for a variety of applications, such as fiber communication systems [1], optical testing [2], fiber sensors [3], and radio-frequency (RF) photonics [4]. Hence, different laser resonator designs for multi-wavelength lasing have been proposed and investigated, such as using the dual Sagnac loop [5], ring cavity [6], compound ring cavity [7], Fox–Smith cavity [8], etc.

Here, several gain media approaches have been proposed, such as employing an erbium-doped fiber amplifier (EDFA) [9], semiconductor optical amplifier (SOA) [5, 10], stimulated Raman scattering [11], stimulated Brillouin scattering (SBS) [12], and the combination of the above methods [13]. However, the SOA could be a better choice over the EDFA because of the nature of inhomogeneous broadening. Moreover, SOA-based lasers have also been used to provide a multi-wavelength fiber laser at room temperature [14, 15].

In this work, to the best of our knowledge, we propose and demonstrate for the first time using a C-band reflective semiconductor optical amplifier (RSOA) with a simple linear cavity to generate multiple wavelengths in the L-band window at room temperature. Thus, two to seven lasing wavelengths can be obtained by adjusting the DC bias currents of the

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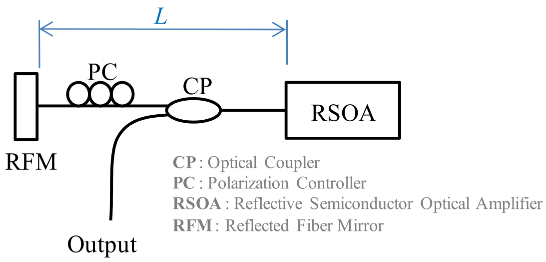

Figure 1. Experimental setup of the proposed multi-wavelength fiber laser configuration with the linear cavity scheme.

RSOA. The laser cavity is simple; it only consists of an RSOA, a polarization controller (PC), a fiber optical coupler (CP) and a reflected fiber mirror (RFM). In addition, the proposed L-band laser is stable, with output power and lasing wavelength fluctuations of ±0.25 dB and ±0.065 nm, respectively.

2. Experiment and discussion

Figure 1 shows the experimental setup of the proposed multi-wavelength fiber laser configuration with the linear cavity scheme. The laser was constructed by an RSOA, a PC, a 1 × 2 and 50:50 CP and an RFM. The RFM had 95% reflection in the C- + L-bands, with insert loss of 0.4 dB. Its polarization dependent loss (PDL) was <0.05 dB and the maximum optical handling power was 300 mW. In the experiment, the RSOA (produced by CIP) could be operated at bias currents from 30 to 80 mA. It had a small signal gain of about 20 dB and polarization dependent gain (PDG) of about 2 dB. It had a noise figure of 8 dB and gain ripple of 0.5 dB. The saturated output power of the RSOA was about 3 dB m. Since the RSOA used in the proposed laser had a PDG of about 2 dB, the PC was used to maintain the polarization state and obtain a maximum output power. Moreover, the output spectrum was observed using an optical spectrum analyzer (OSA) with a resolution of 0.01 nm.

As multiple wavelengths were generated in the proposed laser scheme, the characteristic of the RSOA adopted in the design was crucial to the performance of the proposed laser. Thus, we measured the output amplified spontaneous emission (ASE) spectra of the RSOA under operating currents from 30 to 80 mA. As shown in figure 2, by increasing the DC bias current, the output power of the ASE increased. The center wavelength of the ASE shifted to the shorter wavelength. The gain profile of the RSOA was distributed at the C-band in these bias currents. When the bias current was increased to 80 mA, the ASE reflected by the facets of the RSOA was strong enough to form a resonance cavity; hence lasing occurred.

In the proposed RSOA-based laser, the multi-wavelength lasing could be achieved under proper polarization adjustment. Hence, figure 3 shows the measured output optical spectra of the proposed multi-wavelength laser at the bias currents from 30 to 80 mA. Here, we observe that seven wavelengths can be lased simultaneously when the operating

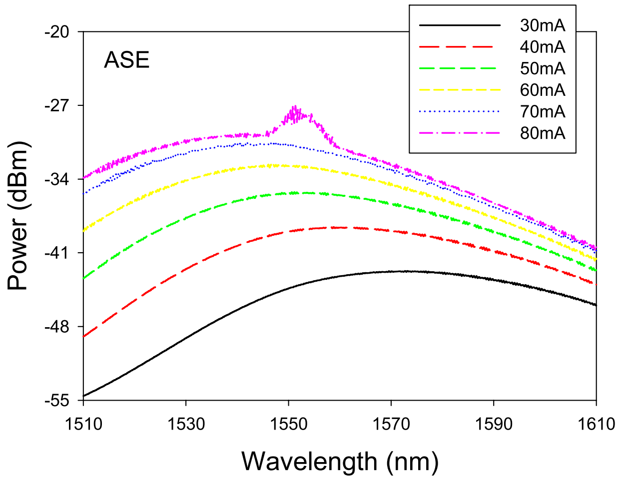

Figure 2. The output ASE spectra of the RSOA at operating currents of 30–80 mA.

current of the RSOA is greater than 40 mA. That is to say, the threshold current of the laser is around 40 mA. The maximum peak power of the lasing wavelength is observed at 1592.62, 1578.88, 1586.74, 1586.68, 1586.68 and 1586.68 nm, respectively, when the bias current is 80, 70, 60, 50, 40 and 30 mA. Previous studies showed that, for high input power, the SOA showed a peak gain shift toward longer wavelength [16]; hence, under the lasing condition at high feedback power, the multi-wavelength laser emits in the L-band window rather than the C-band. In figure 3, the measured mode-spacing under different operating currents is about 2.7 nm. In addition, when the bias current of the RSOA increases, the multi-wavelength lasing shifts to longer wavelength gradually, and the lasing wavelength range is widened gradually too, as shown in figure 3.

Figure 4 shows the number of lasing wavelengths and the peak power difference among these multiple wavelengths when the optical signal to noise ratio (OSNR) is larger than 20 dB. If more than six lasing wavelengths are needed, the bias current should be >40 mA. Besides, figure 4 also presents the peak power difference (ΔP) of multi-wavelength lasing under different bias currents. We observe that the maximum and minimum power differences are 11.3 and 3.9 dB at the bias currents of 50 and 75 mA, respectively. In this measurement, we also measured the output power of the proposed laser at the bias currents from 25 to 80 mA, as shown in figure 5. The output powers are between 0.001 and 0.223 mW.

Finally, in order to verify the performance of 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 80 mA. One of the lasing wavelengths was selected at 1592.06 nm in the measurement. The total observing time was over 20 min. As shown in figure 6, the output power and lasing wavelength fluctuations of ±0.25 dB and ±0.065 nm were measured, respectively. Therefore, experimental results show that the proposed fiber laser has excellent output stabilities. Furthermore, after two hours observing the measurement, the measured output stabilities of the proposed laser are still maintained.

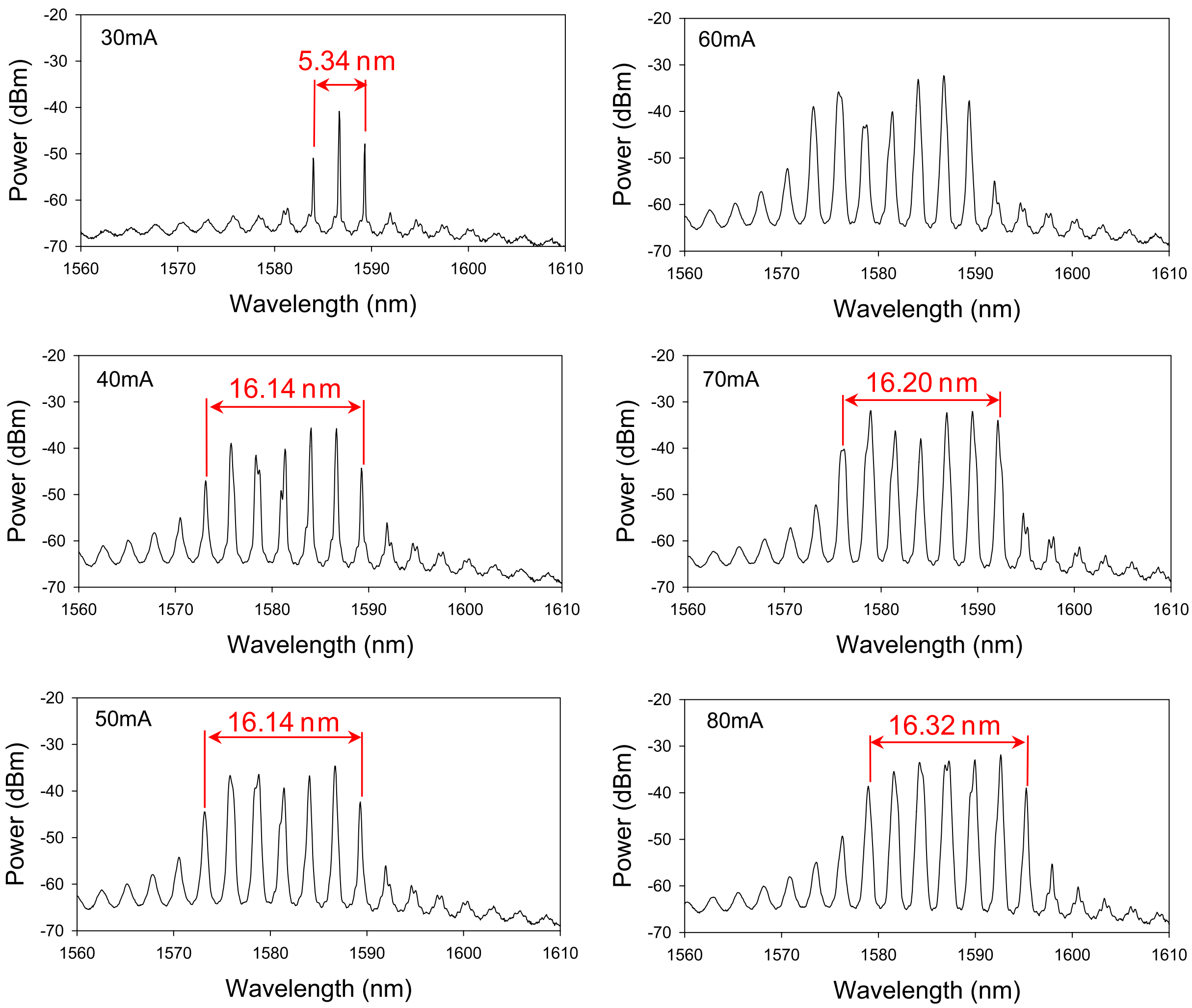

Figure 3. The output spectra of the proposed multi-wavelength laser at bias currents of 30–80 mA.

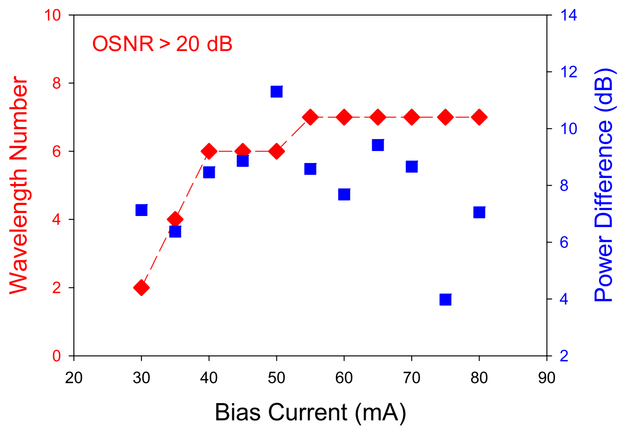

Figure 4. The number of lasing wavelengths in the proposed laser, when the OSNR is larger than 20 dB.

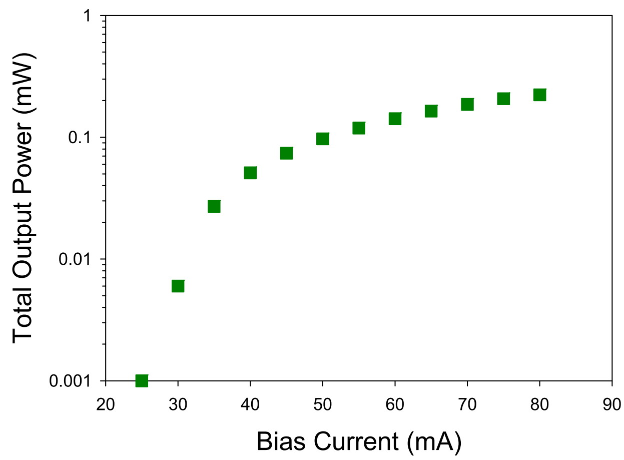

Figure 5. The total output power of the proposed laser at the bias currents of 25–80 mA.

3. Conclusion

We proposed and used for the first time a C-band RSOA with a linear cavity to generate multiple wavelengths in the L-band window at room temperature. Hence, two to seven lasing wavelengths of the proposed multi-wavelength laser can be observed at different bias currents of the RSOA. In this

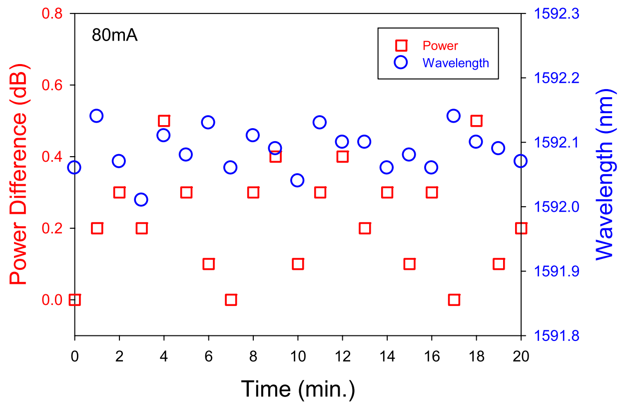

Figure 6. Wavelength variation and power fluctuation of the proposed multi-wavelength fiber laser when the observing time is over 20 min.

measurement, when the bias current is increased gradually, the output power and the number of lasing wavelengths increase. Furthermore, the output power fluctuation and lasing wavelength of the proposed laser are obtained within ±0.25 dB and ±0.065 nm, respectively, and, during two hours observation time, the measured output stabilities of the proposed laser are still maintained.

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