A high-power, power-efficient 1.3-µm SOA-integrated DFB laser for CPO applications

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Abstract: We present a high power 1.3-µm SOA-integrated DFB laser which exhibits a power conversion efficiency of more than 25% with output power of 350 mW up to 45°C. This device also shows an averaged RIN of below -155 dB/Hz.

1. Introductions

Recent progress of AI and machine learning technology drives the demand for more bandwidth of the data center and HPC interconnections. Co-packaged optics (CPO) can address the power consumption and front-panel bottleneck faced by pluggable transceivers [1]. Using of external light sources (ELSs) can effectively remove a power consuming laser die from silicon photonics chip [2]. The ELSs are required to emit at least more than 100 mW of optical power from the facet [3]. The power consumption of the laser occupies the 10–20% among the total power of the CPO engine. Both of high optical power and high electrical-to-optical power conversion efficiency (PCE) are strongly required.

There are several reports on 1.3 µm high-power continuous-wave (CW) DFB lasers, such as large longitudinal-cavity DFB lasers [4] and semiconductor optical amplifier (SOA)-integrated DFB lasers [5, 6]. The SOA-integrated DFB laser structure has benefit in choosing driving conditions for optimizing an optical power, PCE, and RIN. We adopt electrically separated SOA and DFB laser structure as well as a pn current-blocking buried-hetero (BH) structure. A wide-stripe SOA increases the optical power to hundreds mW at the output facet. The fabricated device shows a PCE of 25 % with optical power of 350 mW at 45°C. The lasing spectrum is single-mode over wide range of operating current. In addition, a low level of RIN is possible while maintaining a high optical power and PCE.

2. Device structure

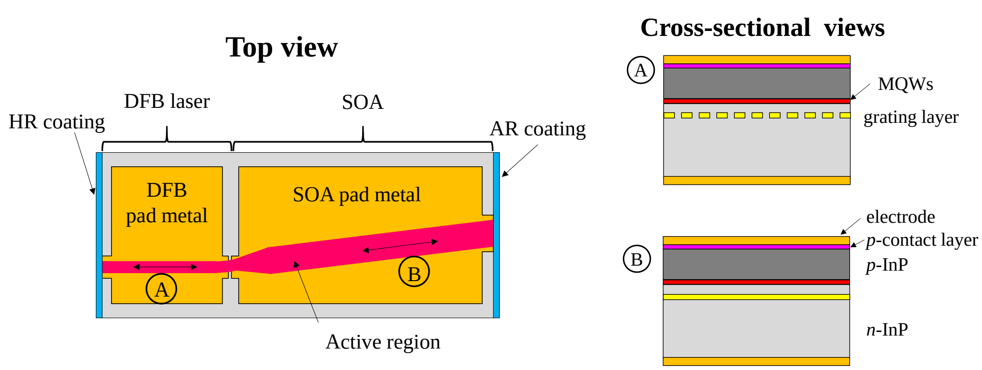

Fig. 1. Schematic of a fabricated SOA-integrated DFB laser. The left figure shows top view, and the right figures show cross-sections.

Figure 1 shows the schematic view of the SOA-integrated DFB laser. The DFB laser with straight mesa-stripe and 7° tilted SOA are connected via a curved and tapered waveguide sections. The taper length is chosen to suppress the higher order transverse modes. The mesa width of the SOA section is 7.2 µm. Total device length is 2 mm. Both DFB laser and SOA sections have same active layer consisting of InGaAsP quantum wells. The active mesa-stripe structure is buried by a pn blocking structure. A high-reflection (HR) and anti-reflection (AR) coatings are formed on the rear side of DFB laser and the front facet of SOA, respectively. The front facet reflectivity is estimated to be lower than -60dB enabled by tilted facet and AR coating confirmed by numerical calculations. The isolation trench is formed between the DFB laser and SOA sections by removing a contact layer. Hence, the DFB laser and SOA can be driven independently.

3. Measurement results

The fabricated devices are mounted on an AlN submount with p-side up configuration. All the measurement has been done with chip-on-carrier (CoC) form under CW driving conditions. Figure 2 (a) shows the optical power-SOA current characteristics of the SOA-integrated DFB laser at stage temperature of 25, 45, and 65°C. The measurements were performed with fixed DFB laser current of 250 mA. The threshold current of the DFB laser is approximately 17 mA at 25°C. The optical output reaches 350 mW with SOA currents of 590 mA at 25°C, and 722 mA at 45°C. Figure 2 (b) shows lasing spectra with SOA current of 300 and 800 mA. The spectrum analyzer resolution is 0.02 nm. The single-mode spectra exhibit a high side-mode suppression ratio (SMSR) of more than 48dB among the measured conditions.

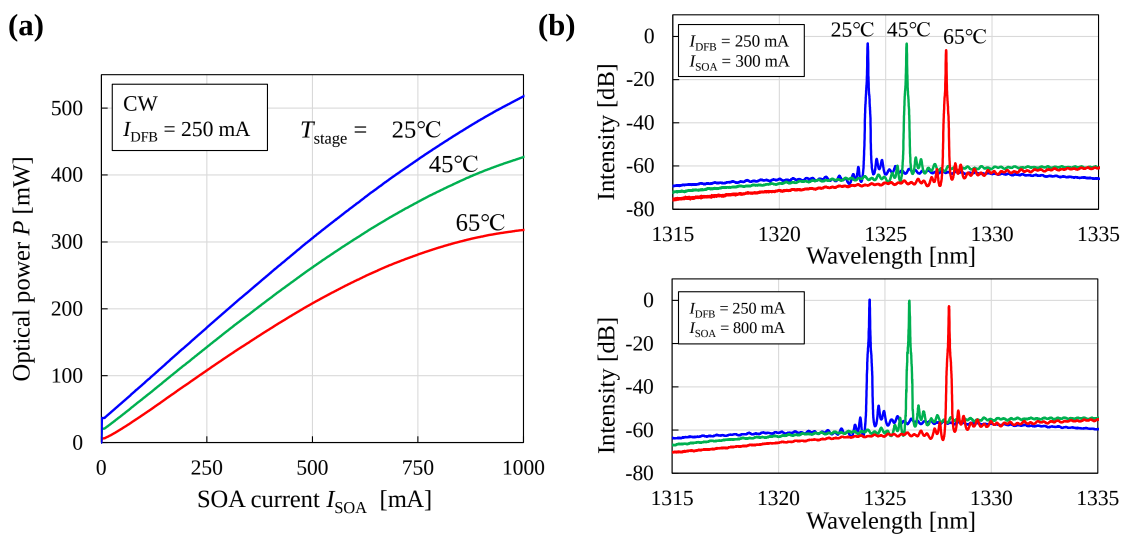

Fig. 2. 25, 45, and 65°C characteristics of CW conditions. (a) Optical power-SOA current, (b) spectra with SOA currents of 300 and 800 mA. The single-mode lasing with the SMSR of more than 48dB is shown.

Figure 3 shows the relationship between the PCE and the optical output power. The PCE of the SOA-integrated DFB laser can be calculated by following expression:

$$\text{Power conversion efficiency (PCE) [\%]} = \frac{\text{Optical power}}{I_{\text{DFB}} \times V_{\text{DFB}} + I_{\text{SOA}} \times V_{\text{SOA}}} \quad (1)$$

Maximum PCEs of 33, 28, and 22% are obtained with output power range of 200–350 mW at 25, 45 and 65°C, respectively. Both the high optical power and PCE are achieved by using a large optical-volume SOA section.

Figure 4 shows the lasing wavelength plot with varying both DFB laser and SOA currents. The plots for stage temperature of 25 and 45°C are shown in a single graph. The DFB currents are changed from 17.5–350 mA with 17.5 mA step. The red shift of the peak wavelength is smaller than the DFB mode spacing of approximately 0.3 nm. No evidence of mode-hop is observed. Keeping the DFB cavity short leads us to achieve the stable single-mode operation and avoid serious spatial-hole burning (SHB) effect even at a high injection condition.

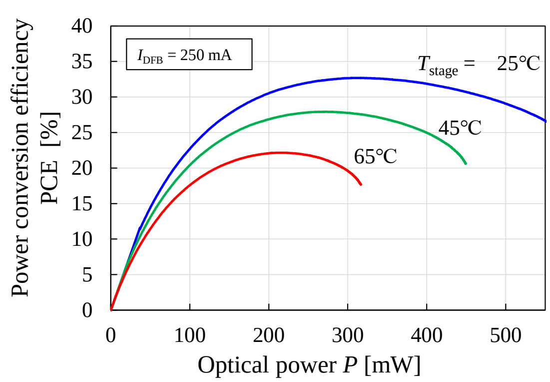

Fig. 3. PCE versus optical power characteristics at 25, 45, and 65°C.

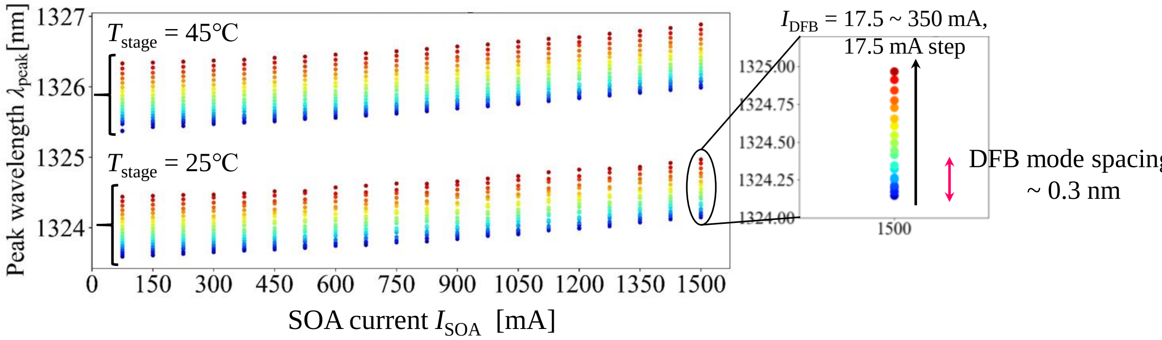

Fig. 4. Lasing wavelength plots at T_{stage} of 25 and 45°C. The colors of the plots represent the DFB laser currents. The wavelength shift is smaller than the DFB mode spacing of 0.3 nm, and no mode-hop occurs.

The optimum driving conditions are investigated in terms of optical power, PCE, and averaged RIN. Figure 5(a) shows the optical power map at 45°C plotted with different pair values of currents on DFB laser and SOA. The contour with solid line indicates the optical power of 350 mW. The added contour line in fig. 5(b) indicates the PCE of 25%. The area closed by the two contours satisfies both optical power of more than 350 mW and the PCE of more than 25%. Finally, the RIN was also measured with pair values of currents on DFB laser and SOA. The RIN was measured in frequency range from 0.1 to 26.5 GHz and averaged over frequency in linear scale and then converted to log-scale. Figure 5(c) shows the averaged RIN map at 45°C. The contours indicate the RIN below -145, -150 and -155 dB/Hz. We can find that there is driving conditions which satisfies all the conditions of optical power > 350 mW, PCE > 25%, and averaged RIN < -155 dB/Hz. These results indicate that the SOA-integrated DFB lasers are applicable for high-power and high efficiency external light source for CPO applications.

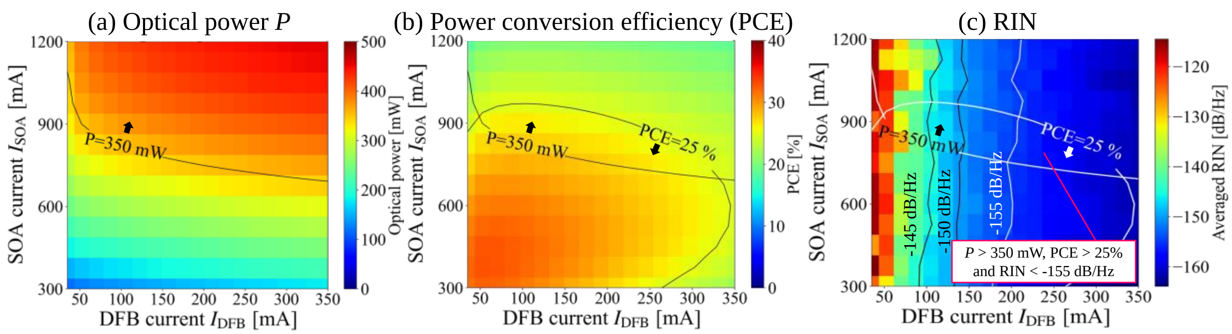

Fig. 5. Characteristic maps at 45°C with pairs of currents on DFB laser and SOA for (a) optical power P, (b) power conversion efficiency (PCE), and (c) averaged RIN. There are driving conditions which satisfy optical power > 350 mW, PCE > 25%, and RIN < -155 dB/Hz.

4. Conclusion

An SOA-integrated DFB laser is introduced as an external light source of CPO applications. The fabricated device shows the optical power of more than 500 mW at 25°C. The optical power of 350 mW at 45°C is obtained with the PCE of more than 25% and averaged RIN of below -155 dB/Hz by choosing driving currents on DFB laser and SOA.

5. References

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