Over 100 mW Uncooled Operation of SOA-integrated 1.3-µm Highly Reliable CW-DFB Laser

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Abstract: We demonstrate the first SOA-integrated CW-DFB laser at 1.3 µm with kink-free and stable single-mode operation over 100 mW at up to 80 ºC. We also achieved reliable operation over 700 hours at 80 ºC.

1. Introduction

With the recent and future expected increase of data center traffic, silicon photonics (SiPh) including co-packaged optics is attracting attention as a potential cost-effective high-speed optical transmission solution. Mach-Zehnder (MZ) modulator is a widely used SiPh modulator, however one of the problems is that as the baud rate increases the optical insertion loss becomes large, due to its low modulation efficiency [1]. Highly reliable high-power continuous wave distributed feedback (CW-DFB) lasers are necessary to support these SiPh technologies. There are several approaches for this challenge. One approach is to use single ultra high-power CW-DFB laser like 1 W [2], and the other is to use more than two lower power CW-DFB lasers. Recent studies focused around laser power consumption efficiency may result in some use cases adopting two or more lasers rather than using the ultra high-power laser [3]. Previously, several studies have been demonstrated for high output power 1.3 µm DFB lasers at low temperatures [4,5]. Uncooled operation is preferable for low energy consumption as it does not require thermoelectric cooler. However, high output power at higher temperature, such as 80 ºC has not been reported yet.

To further realize highly reliable high-power CW-DFB lasers under uncooled operation, we demonstrate a semiconductor optical amplifier (SOA)-integrated CW-DFB laser. To the best of our knowledge, this is the first SOA-integrated CW-DFB laser operating at 1.3 µm under uncooled condition. The laser is optimally designed to achieve stable, high-power and high reliability. The fabricated laser exhibits kink-free stable longitudinal single-mode operation over 200 mW at 20ºC and 100 mW at 80ºC. For good coupling efficiency between the CW-DFB and Si waveguide, spot size converter (SSC) is also integrated, which is designed to control the far field pattern (FFP) of the output beam. Highly reliable operation is also proven by over 700 hours aging test at 80ºC.

2. Device Structure

Figure 1 shows the schematic of the fabricated SOA-integrated DFB laser. It consists of a DFB laser and SOA. SOA also functions as SSC by changing its waveguide width. The LD section of uncooled EA-DFB [6], whose high reliability has already been proven, is adopted as a DFB laser. The epitaxial layers of the device were grown on a n-InP substrate by metal-organic chemical vapor deposition (MOCVD). The MQWs are InGaAsP-based, and the mesa structure including the MQWs are formed by dry etching and was buried with semi-insulating InP (SI-InP).

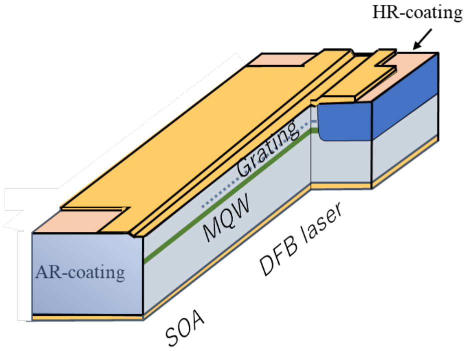

Fig 1. Schematic view of fabricated SOA-integrated laser

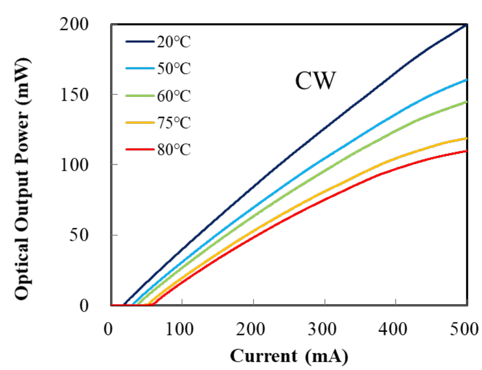

Fig 2. I-L characteristics at 20, 50, 60, 75, and 80ºC

The doping profile and coupling coefficient of the DFB laser (κ) have been optimized to achieve high optical output power. DFB laser, SSC, and SOA are composed of the same materials and formed by the same process, so that each layer of the laser lies from the rear to the front of the laser uniformly. SOA is integrated to reduce τ_p, which resulted in the decrease of the internal loss and to boost the optical output power. SOA and SSC are optimally designed and integrated to amplify 20% of DFB laser and reach 100 mW optical output power. For high optical output power, an anti-reflection (AR) film (with a reflectivity of lower than 0.1 %) and a high-reflection (HR) film are coated on the front and the rear facets of the laser respectively. The integrated SOA and the DFB laser have one common electrode, so only one power supply is required. Moreover, SSC is designed just by adjusting the mesa width, which does not need any additional process. The total length of the DFB laser and SOA is 1 mm. The lasers are mounted n-side down.

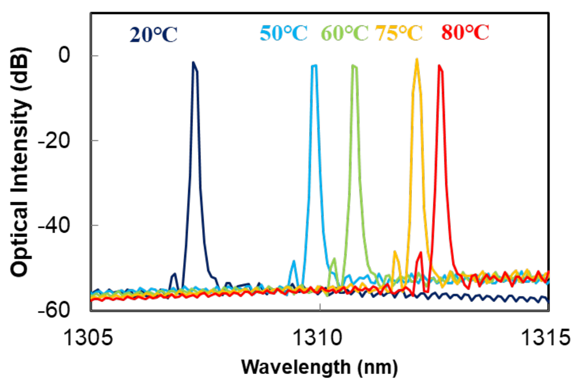

Fig 3. Optical spectrum at each temperature

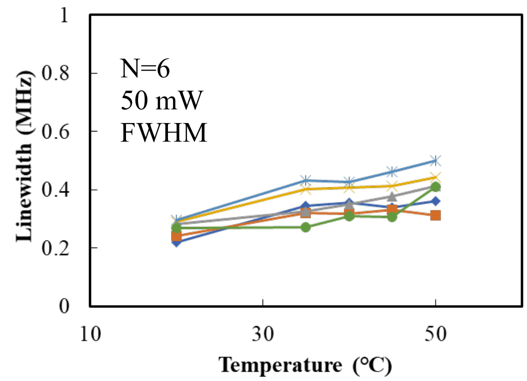

Fig 4. Linewidth characteristics

3. Measurement Results

Figure 2 shows the I-L characteristics of the CW-DFB laser at 20, 50, 60, 75 and 80ºC. The measurements were performed under CW operation. The threshold current is about 50 mA and the kink-free operation is excess 100 mW with 500 mA operating current at 80ºC. The output power reaches over 200 mW at 20ºC and 100 mW at 80ºC with operating current of 500 mA. By optimizing the doping profile and κ, the increase of optical output power and a good high temperature characteristic were achieved. The optical spectrums at 20, 50, 60, 75, and 80ºC are shown in Fig. 3. It shows a stable longitudinal single-mode operation with center lasing wavelength of 1307 nm and 1312 nm at 20 and 80ºC respectively. Side-mode suppression ratio excess 40 dB at all temperatures. Figure 4 shows linewidths of six samples at 50 mW are below 500 kHz up to 50ºC, which is narrow enough as CW-DFB lasers. The linewidths were determined at FWHM.

SSC is introduced to the laser chip to control the divergence angle of the output beam. Figure 5 shows the relation between the normalized width of SSC and FFP of the output beam. Both vertical and horizontal FFP gets small when the SSC width becomes narrow. Figure 6 shows typical FFP without SSC at 50 mW. It fits Gaussian profile, which results in high coupling efficiency with other optical components, such as waveguides and fibers. RIN characteristics and reliability are also important for SiPh-CW lasers. Figure 7 shows the RIN characteristics with different external optical feedbacks. Smaller than -150 dB/Hz was achieved with external optical feedback of up to -25 dB. Aging test was conducted to prove the reliability of this laser. Figure 8 shows the result of aging test with the condition of auto current control (ACC), 80ºC and 300 mA operating current. The output power remains constant for over 700 hours.

Figure 9 shows the comparison between this work and previously reported works. Solid square represents the result of this work. As shown in this figure, the optical output power of this work exceeds the results of previously reported works. This is the first report that is over 100 mW at 75ºC.

4. Conclusion

To the best of our knowledge, we demonstrated the first SOA-integrated CW-DFB laser at 1.3 μm under uncooled operation. The BH structure, applied to the LD section of CW-DFB laser, already has been widely used with EA-DFB and has proven sufficient reliability. We achieved optical output power of 100 mW at 80ºC with 1 mm chip length and SMSR excess 40 dB at all temperatures from 20ºC to 80ºC. By introducing SSC, we demonstrated that the FFP of the output beam can be controlled. From the RIN spectrum, the CW-DFB laser can endure about -25 dB optical feedback, and this indicates a possibility of isolator-free operation. Moreover, we have proven over 700 hours reliability by aging test at 80ºC. We believe this CW-DFB laser is a promising candidate as a light source of SiPh.

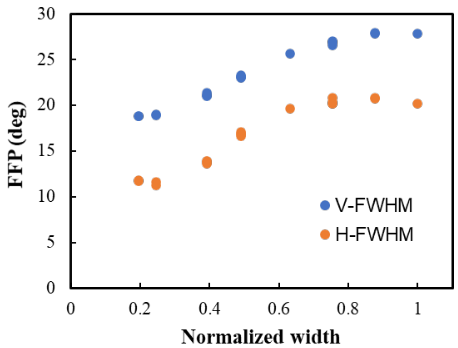

Fig 5. Relation between normalized width of SSC and FFP

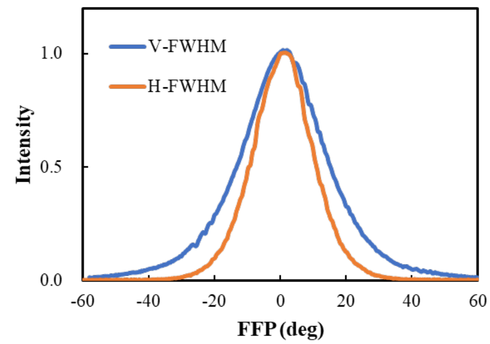

Fig 6. Measured far field patten (Normalized width: 1)

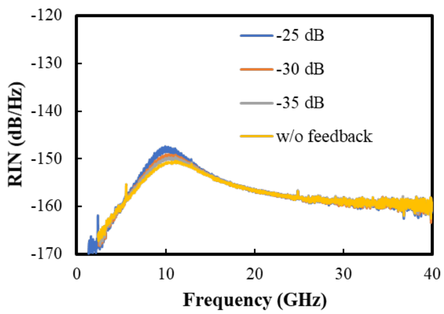

Fig 7. RIN characteristics with different external optical feedback

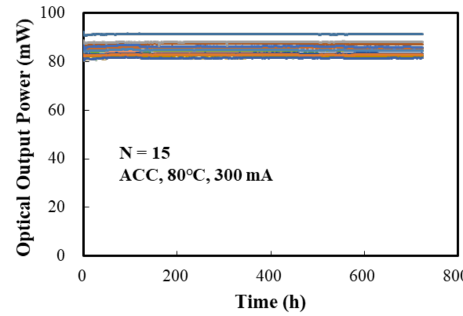

Fig 8. Result of aging test.

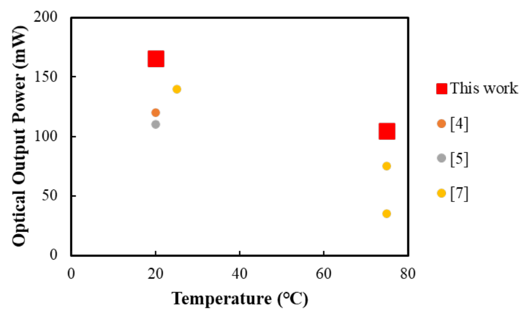

Fig. 9 Reported relations between temperature and optical output power

5. References

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