Extended Abstracts of the 1997 International Conference on Solid State Devices and Materials, Hamamatsu, 1997, pp. 50-51 **C-1-3**

Invited
High Temperature Operation of a 1.3-μm Spot-Size-Converter Integrated Laser Diode (SS-LD)

Yuichi Tohmori and Yoshio Itaya

NTT Opto-electronics Laboratories
3-1, Morinosato Wakamiya, Atsugi-shi, Kanagawa-pref., 243-01 Japan
phone; +81-462-40-3161, facsimile; +81-462-40-3186,
e-mail; tohmori@aecl.ntt.co.jp

1. Introduction

Laser diodes (LDs) operating up to high temperature with high reliability are required in the low-cost optical modules used in access networks, such as fiber to the home or the curb [1]. These LDs are also required to have low-loss coupling to an optical fiber and a planer lightwave circuit (PLC) without lenses as well as large alignment tolerance in assembling the modules. Several investigations have produced such LDs by monolithically integrating the spot-size converter. Here, the spot-size of the oscillating light is expanded to match those of the optical fiber and the PLC [2]~[5].

We have developed a spot-size converter integrated LD (SS-LD) in which the spot-size converter is butt-jointed to the lasing active region [6]. With this structure, the active and spot-size converter regions are independently optimized for high-temperature lasing operation and low-loss coupling to the fiber and waveguide respectively.

In this paper we report the high temperature characteristics for the SS-LD.

2. SS-LD structure

The structure of the 1.3-µm SS-LD is shown in Fig. 1. A taper-layer in the SS region is butt-jointed to the active layer [7]. The active layer consists of a compressively strained multi-quantum-well (MQW) structure with eight wells in order to increase the maximum operation temperature effectively [8]. A strain of 1.2% is introduced to the 6-nm-thick InGaAsP wells. The band-gap wavelength of the barriers and the separate-confinement heterostructure (SCH) are both 1.1 µm.

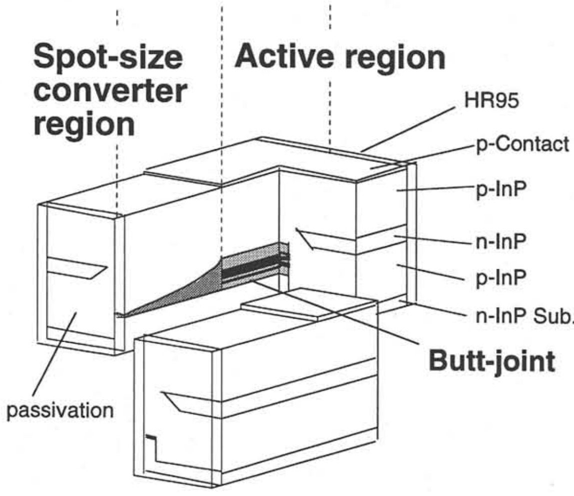

Fig. 1 Schematic structure of a 1.3-µm spot-size-converter integrated laser.

The taper layer consists of a 1.1-µm-bandgap bulk layer which has very low loss for a 1.3-µm oscillating light in the active layer. The taper-layer thickness changes exponentially from 0.3-µm at the butt-joint portion to 0.1-µm at the front facet. This change effectively reduces radiation loss in the SS region. The peak-wavelength from micro-photoluminescence (PL) changes slightly from 1.13 µm to 1.09 µm in this taper layer.

The device is fabricated by 2-inch full-wafer processes using five MOVPE growth steps. A vertical-taper layer structure is formed by a selective butt-joint growth [6]. During this growth process the taper layer is butt-jointed to the active layer. The BH mesa is formed by $CH_4 + H_2$ dry etching and is buried by p- and n-type InP current blocking layers. A buffer layer is inserted between the side wall of the dry-etched mesa and the p-InP blocking layer to eliminate Zn diffusion [9]. The surface of the device is perfectly flat except for the slight step of less than 0.2 µm above the mesa structure. The length of the active and SS regions are both 300 µm. The device is high-reflection coated (reflectivity: 95%) at the rear facet.

3. High temperature characteristics

The temperature dependence of the current to light output characteristics in the SS-LD is shown in Fig. 2. Threshold current (I_{th}) and driving current at 10-mW output-power (I_{10mW}) are 5.6 mA and 30.5 mA respectively at 25°C and 15.8 mA and 51.7 mA respectively at 85°C. The maximum operation temperature (T_{max}) of 134°C is achieved.

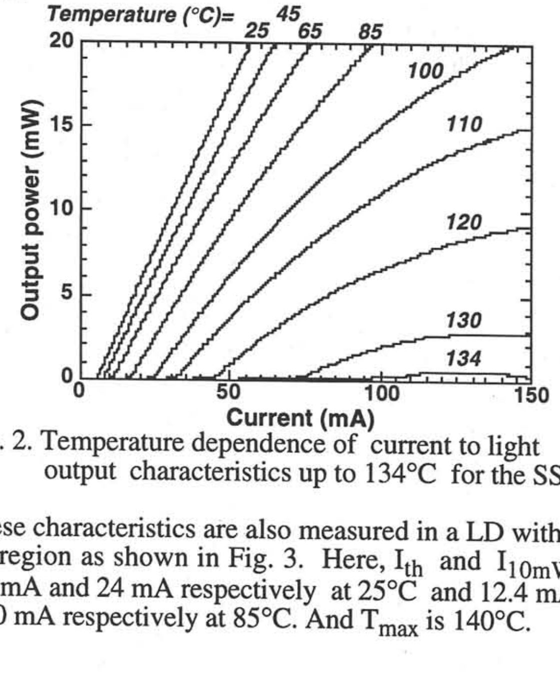

Fig. 2. Temperature dependence of current to light output characteristics up to 134°C for the SS-LD.

These characteristics are also measured in a LD without a SS region as shown in Fig. 3. Here, I_{th} and I_{10mW} are 3.9 mA and 24 mA respectively at 25°C and 12.4 mA and 40.0 mA respectively at 85°C. And T_{max} is 140°C.

The characteristic temperature of the threshold current T_0 between 25 and 85°C for the LDs with and without SS regions are 57 K and 52 K respectively (Fig. 4). Concerning the temperature characteristics of T_{max} and T_0, an influence due to integrating the SS region into the LD is sufficiently small .

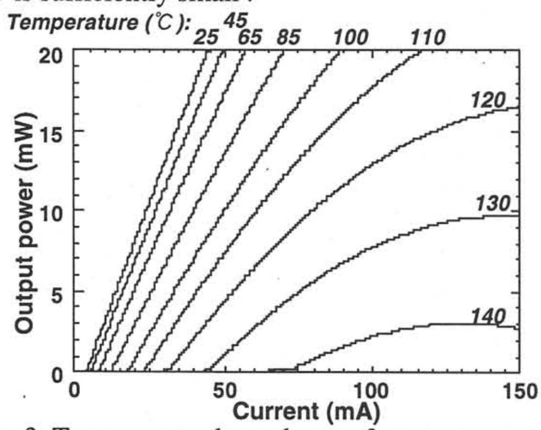

Fig. 3. Temperature dependence of current to light output characteristics up to 140°C for the LD without a SS region.

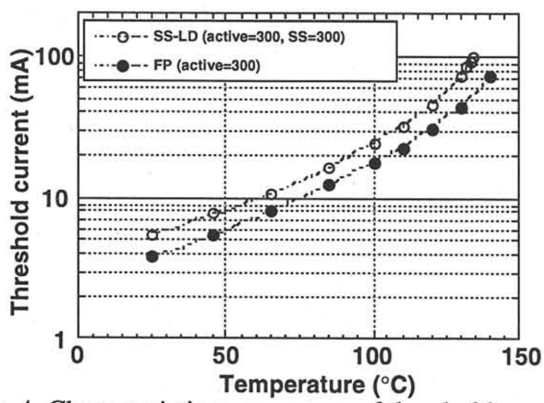

Fig. 4. Characteristic temperature of threshold current T_0 for LDs with and without a SS region.

The optical coupling loss between the SS-LD and a dispersion-shifted fiber (DSF) is 1.5 dB at 10-mW output and 25°C. The temperature dependence of the coupling loss is shown in Fig. 5. In this figure stable coupling loss around 1.5 dB is confirmed at the temperature range from 25 to 85°C.

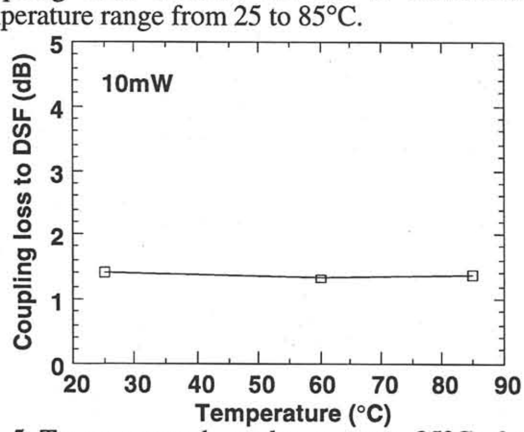

Fig. 5. Temperature dependence up to 85°C of coupling loss to DSF.

Reliability of the SS-LD for access networks needs to be confirmed at high temperature. Figure 6 shows aging-test results for 10 samples operating at 60°C under constant power of 10 mW. No large increase in the driving current can be observed up to 10^4 hours of operation. During long-term operation, T_0 and FFPs are nearly constant [10]. By linear extrapolating the degrading trend with the failure criterion set at a 30% increase in the initial operation current, the median life was estimated to be more than 10^5 hours at a constant power of 10 mW and 60°C. These results show that the SS-LD can be applied in access network applications which require high reliability up to high temperature.

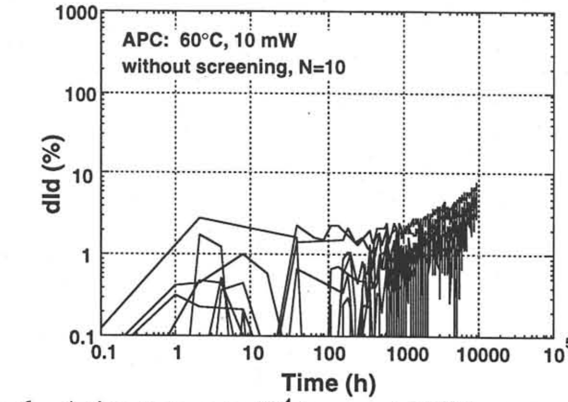

Fig. 6. Aging test up to 10^4 hours at 60 °C under a constant output power of 10 mW.

5. Summary

1.3-μm SS-LDs have been successfully fabricated by butt-joint integration. Good high-temperature characteristics are demonstrated for threshold current, output power, and coupling. Long-term stability for the SS-LDs was also confirmed.

References;

[1] J. Yoshida, Proc. of IEEE Workshop on Optical Access Networks, pp. 6.1-1-6.1-8, Sept., 1995.

[2] T. L. Koch, U.Koren, G.Eisenstein, M.G.Young, M.Oron, C.R.Giles, and B.I.Miller, IEEE Photon. Technol. Lett., vol. 2, No. 2, pp. 88-90, Feb., 1990.

[3] K. Kasaya, Y.Kondo, M.Okamoto, O.Mitomi, and M.Naganuma, Electron. Lett., vol. 29, No. 23, pp. 2067-2068, Nov., 1993.

[4] I. F. Lealman, L.J.Rivers, M.J.Harlow, S.D.Perrin, and M.J.Robertson, Electron. Lett., vol. 30, No. 11, pp. 857-856, May, 1994.

[5] H. Kobayashi, M.Ekawa, N.Okazaki, O.Aoki, S.Ogita, and H.Soda, IEEE Photon. Technol. Lett., vol. 6, No. 9, pp. 1080-1081, Sept., 1994.

[6] Y. Tohmori,Y.Suzaki, H.Oohashi, Y.Sakai, Y.Kondo, H.Okamoto, M.Okamoto, Y.Kadota, O.Mitomi, Y.Itaya, andT.Sugie, Electron. Lett., vol.31, No. 21 pp. 1838-1840, Oct., 1995.

[7] Y.Tohmori and M.Oishi, Jpn. J. Appl. Phys., vol.27, pp. L693-L695, 1988.

[8] S. Seki, H.Oohashi, H.Sugiura, T.Hirono, and K.Yokoyama, IEEE Photon. Technol. Lett. vol. 7, No. 8, pp.839-841, Aug., 1995.

[9] Y. Kondo, K.Kishi, M.Itoh, H.Oohashi, Y.Itaya, and M.Yamamoto, IPRM, TuB2-3, p. 384, 1996.

[10] H.Oohashi, M.Fukuda, Y.Kondo, M.Wada, Y.Sakai, and Y.Tohmori, Proc. of ECOC'96, vol.2, ThC-24, 1996.