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Room-temperature continuous-wave operation of GaInNAsSb laser diodes at 1.55 μm

J.A. Gupta, P.J. Barrios, X. Zhang, J. Lapointe, D. Poitras, G. Pakulski, X. Wu and A. Delâge

The first 1.55 μm room-temperature continuous-wave (CW) operation of GaAs-based laser diodes utilising GaInNAsSb/GaNAs double quantum well active regions grown by molecular beam epitaxy is reported. In electrically-pumped CW operation the narrow ridge waveguide devices have a room temperature lasing wavelength of 1550 nm near threshold, increasing to 1553 nm at thermal rollover. The CW threshold current was 132 mA for a 3 × 589 μm device, with a characteristic temperature of 83 K, measured in pulsed mode between 20 and 70°C.

Introduction: Recently, several reports have illustrated the promise of dilute nitride, GaAs-based lasers with continuous-wave (CW) operation near 1.5 μm [1–3]. However, to adequately address the needs of long-haul fibre transmission, the output wavelength of such devices must be further red-shifted, and we recently reported pulsed operation of GaInNAsSb laser diodes at 1532 nm [4]. In this Letter we present results of GaInNAsSb/GaNAs double quantum well lasers with record CW lasing wavelength of 1553 nm at room temperature. This encouraging result suggests that further optimisation may soon lead to devices suitable for C-band operation.

Fabrication: The molecular beam epitaxy (MBE) growth of these devices was described recently [4]. Briefly, the devices employ a step-index separate confinement heterostructure design, using Si and Be-doped $Al_{0.33}Ga_{0.67}As$ cladding layers. The active region, grown at 415°C, nominally consists of two 7 nm $Ga_{0.61}In_{0.39}N_{0.027}As_{0.962}Sb_{0.011}$ quantum wells with 20 nm $GaN_{0.044}As_{0.956}$ barriers, within a 371 nm GaAs waveguide. Before fabrication, the wafer was annealed at 700°C, for 300 s under flowing N_2 with GaAs proximity capping.

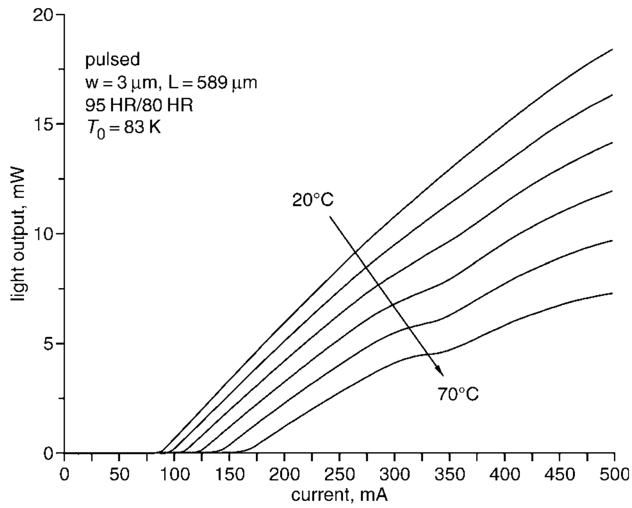

Fig. 1 *Temperature-dependent light output (L) against applied current (I) for laser diode of width 3 μm and length 589 μm in pulsed operation*
Device has 95 and 80% high-reflectivity mirror coatings

Ridge-waveguide (RWG) lasers were fabricated using inductively-coupled-plasma reactive ion etching (ICP-RIE) with standard Ti-Pt-Au and Au-Ge-Ni p- and n-contacts deposited by electron beam evaporation. Lateral leakage currents were reduced compared with previous work [4] by increasing the etch depth outside the ridge to leave only 100 nm of p-cladding above the waveguide. This compromises the single-lateral-mode behaviour, but was important for reducing the lateral leakage current in order to achieve CW operation with this particular laser structure. The lasers were cleaved into bars with Fabry-Perot cavity lengths of 589 μm and the facets were coated with a-Si/SiO_2 high-reflectivity coatings using ion beam sputter deposition. The design reflectivities of the back and front (output) facets were 95 and 80%, respectively. The coated devices were mounted p-side up onto alumina carriers and tested on a thermoelectric temperature stage. Measurements were made in both CW mode and pulsed mode with a 1% duty cycle and the output power was measured using a calibrated Ge detector. The emission spectra were measured using an optical spectrum analyser.

Results: Temperature-dependent measurements of a narrow, 3 μm-wide RWG device were made in pulsed mode with a 1% duty cycle and 1 μs pulse width, as shown in Fig. 1. At 20°C the threshold current was 88 mA, and the characteristic temperature, T_0, was found to be 83 K from 20 to 70°C. Similar devices with uncoated facets exhibited T_0 values near 67 K, while a single 95% HR back-facet coating resulted in $T_0 = 73$ K.

Fig. 2 shows the light output and voltage with input current (*L–I–V*) curves in CW operation at several temperatures. The RT threshold current was found to be 132 mA and both the threshold current and light output improved as the operating temperature was reduced towards 10°C. This suggests that thermal management remains a challenge in the present devices. The diode characteristics were relatively unchanged over the same range and the turn-on voltage was close to the quantum well bandgap of 0.8 eV.

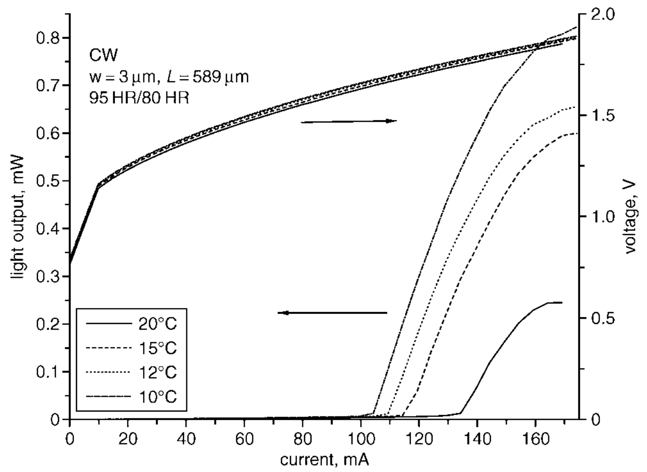

Fig. 2 *Light output and voltage against applied current for 3 × 589 μm HR(98%)/HR(98%) laser diode in CW operation at several temperatures*

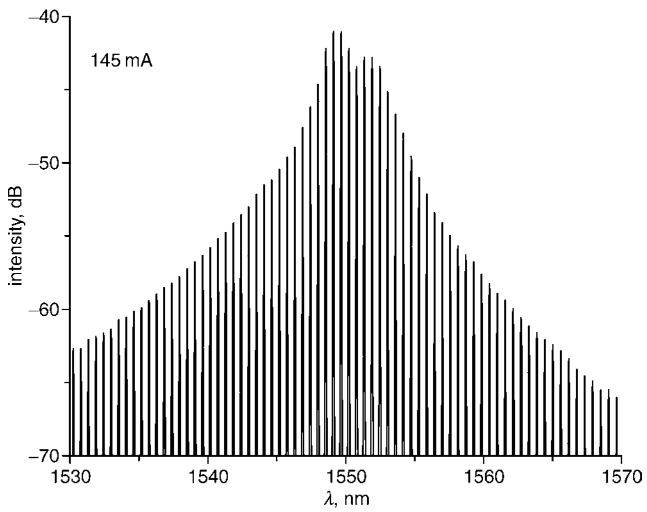

Fig. 3 *CW output spectrum with 145 mA drive current at 20°C*

Just above threshold the device exhibits CW light output near 1550 nm at 20°C with well-defined Fabry-Perot features as shown in Fig. 3. Near thermal rollover, the device exhibits single-lateral-mode output with a peak wavelength of 1553 nm (Fig. 4).

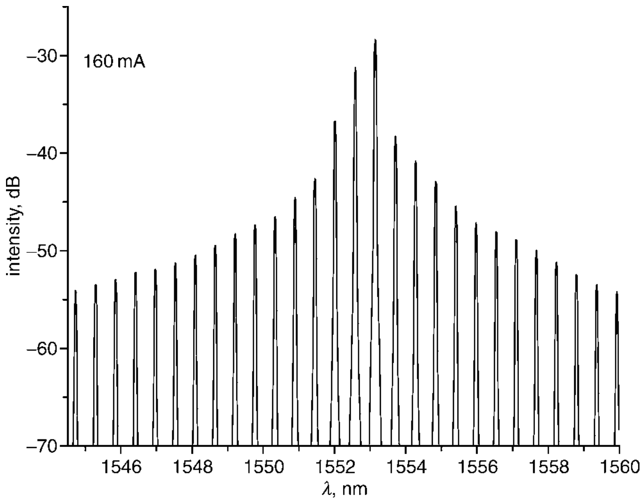

Fig. 4 *CW output spectrum with 160 mA drive current at 20°C*

Conclusions: We have demonstrated 1550 nm room-temperature CW operation of GaInNAsSb RWG laser diodes on GaAs. To our knowledge, this is the longest CW lasing wavelength achieved for GaAs-based lasers. With small improvements in the device design, lower-threshold, stable devices with higher output power are anticipated.

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References

1 Gollub, D., Moses, S., Fischer, M., Kamp, M., and Forchel, A.: 'GaInNAs-based distributed feedback laser diodes emitting at 1.5 µm', *Electron. Lett.*, 2004, **40**, pp. 427–428
2 Bank, S.R., Wistey, M.A., Goddard, L.L., Yuen, H.B., Lordi, V., and Harris, J.S.: 'Low-threshold continuous-wave 1.5 µm GaInNAsSb lasers grown on GaAs', *IEEE J. Quantum Electron.*, 2004, **40**, pp. 656–664
3 Yokozeki, M., Mitomo, J., Sato, Y., Hino, T., and Narui, H.: '1.5 µm CW operation of GaInNAs/GaAs laser diodes grown by MOCVD', *Electron. Lett.*, 2004, **40**, pp. 1060–1061
4 Gupta, J.A., Barrios, P.J., Zhang, X., Pakulski, G., and Wu, X.: '1.53 µm GaInNAsSb laser diodes grown on GaAs(100)', *Electron. Lett.*, 2005, **41**, pp. 71–72