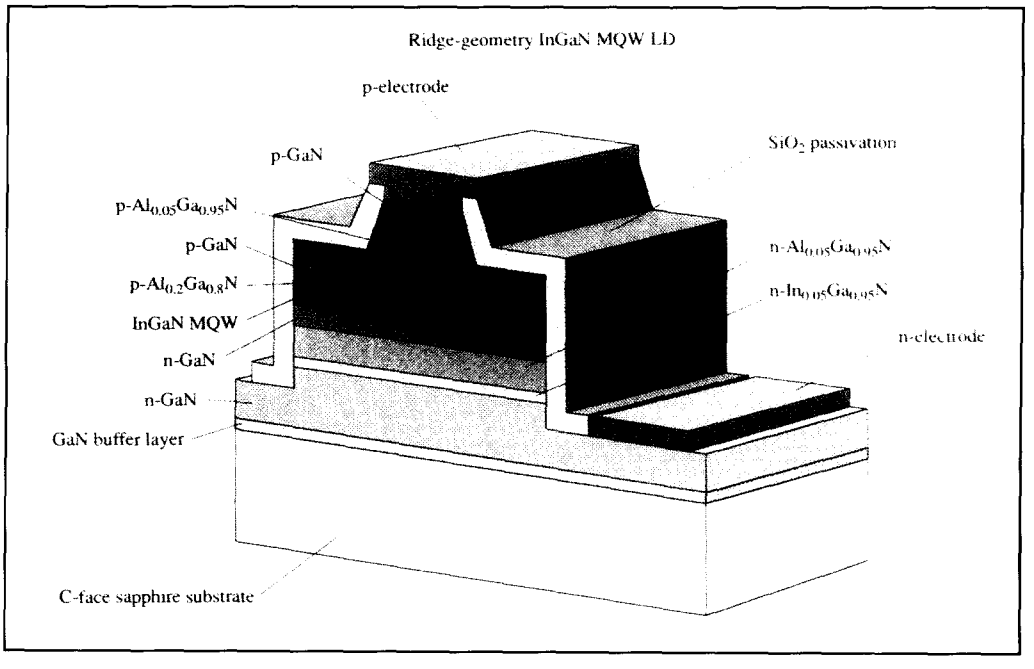
Nichia Warms the Pace for CW Blue Laser

by Roy Szweda

In the *Applied Physics Letters* journal Dr Shuji Nakamura and his colleagues have recorded their success in "the first continuous-wave operation of InGaN multi-quantum-well-structure laser diodes at 233K". Pulsed operation at RT has previously been demonstrated (see *III-Vs Review* Vol. 9 No. 3, p22) but the target is for CW operation in order to realise practical manufacturable blue emitting lasers for high density data storage for DVD etc. This recent achievement is a notable step in the path to this goal.



As before, the lasers were prepared using the Nichia-developed two-flow MOCVD method at atmospheric pressure using (001) C-face sapphire substrate. The structure of the laser diode is complex and best seen as a pictorial representation as shown here. Key to the growth and integrity of the layers are the n-type InGaN buffer and thick AlGaN which prevents film cracking. As Dr Nakamura says, the structure of the ridge-geometry InGaN MQW was almost the same as that used before. This was formed by etching of the surface of the p-type GaN layer. The mirror facet was formed by dry etching also.

Since the objective of the work was to achieve RT operation these diodes were actually tested under these conditions at this temperature but "were easily broken within one second due to heat generation". However, CW operation was subsequently confirmed when the temperature was reduced to 233K (i.e. -40°C) by immersion in ethanol cooled by dry ice. It was under these conditions that DC electrical characterization was performed. Up to a threshold current of 210 mA no stimulated emission took place. However, a differential quantum efficiency of 8% per facet and 9.5 mW per facet output were gained at 250 mA.

It is worth pointing out that the paper describes improvement in operating voltage – these measurements were made at 11 V contrast this to that used before i.e. 30V. This was achieved by "adjusting growth, ohmic contact and doping profile conditions".

Pulsed operation of these diodes was also successful with lasing occurring between 283K and 343K. Temperature range was determined by the limits of the measurement equipment. Dr Nakamura estimates the temperature dependence of the threshold current to be 162K.

Temperature control was also a problem for measurement of emission spectra. In fact it is unknown as yet how much longer than the 30 min used here that these diodes would continue to operate at 233K but "it is expected to be longer".

The optical characteristics of the diode were also measured and spontaneous emission noted at a peak wavelength of 409 nm with a broad spectral width of 20 nm. It is noted that observed peaks had separations which differ from those seen with pulsed operation. Dr Nakamura infers that the previously seen multiple sharp peaks were characteristic of the pulsed current flow. However, it may also derive from inhomogeneities in film thickness and composition of layers and so on. The paper also discusses excitation behaviour and considers their relation to emission mechanism in this type of diode. It is deemed unlikely that excitons are related to emission at RT, unlike circumstances in other devices such as S- and M-QW LEDs.

Next Issue

In the next issue we will return to the LED developments at Nichia and also look at their growing application in outdoor displays.

Reference

The paper is: S. Nakamura, M. Senoh, S. Nagahama, N. Iwasa, T. Yamada, T. Matsushita, Y. Sugimoto and H. Kiyoku, "The first continuous-wave operation of InGaN multi-quantum-well-structure laser diodes at 233K", *Appl. Phys. Lett., November 11 (1996) in press.*

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