Abstract

This work focuses on the measurement and simulation of 1.3μm InGaAsN/GaAs edge-emitting quantum well (QW) laser diodes. An experimental system has been developed, which is capable of measuring the below threshold amplified spontaneous emission spectra (ASE) over a wide range of heat sink temperatures. The ASE spectra from a series of InGaAsN/GaAs devices was measured allowing both gain and effective group index as a function of temperature and injection current to be determined. The performance of the material system was found comparable to the more traditional InP-based devices giving a low cavity loss, high gain and good thermal stability of lasing wavelength. For the first time, the above threshold front facet temperature and quantum well temperatures of these state-of-the-art devices have been determined as a function of injection current and heat sink temperature. Continuous lasing operation with an internal QW temperature of over 440K was demonstrated. This suggests that the dilute nitride material system could be a viable competitor to InP-based devices, but with the added ability to operate uncooled at increased heat sink temperatures.

The experimental work is followed by the extension of an isothermal electro-optical laser device simulator to include thermal effects. This model is then used to investigate the thermal performance of the InGaAsN/GaAs devices. Good agreement is found between measured device temperature and simulated temperature. The model is used to investigate possible design improvements. It is found that for a mesa structure a significant reduction in QW temperature can be achieved by p-side down mounting.

The transport of lattice heat out of opto-electronic devices is also examined, with particular attention being paid to the small but measurable thermal resistance associated with epitaxial interfaces. To include this effect in the full device simulator, a robust discretisation scheme is derived capable of including a step wise temperature drop at the interface. It is found that for a device with a relatively small number of interfaces the effect can lead to a 0.5K increase in QW temperature. For a device with a larger number of interfaces (e.g. VCSEL mirrors) a temperature increase of up to a 5K increase across the structure is predicted.

For the first time, the generation of a non-equilibrium hot phonon population around the QW in a 1.3μm InGaAsN/GaAs structure is studied. It is found that, the hot LO-phonon population generated by carriers relaxing from the bulk to the bound states can elevate the confined carrier temperature by up to 20K above that of the lattice. The increased carrier temperatures predicted are found to significantly reduce the device gain and consequently device performance.