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Broad-band Superluminescent Light Emitting Diodes Incorporating Quantum Dots in Compositionally Modulated Quantum Wells

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Introduction

Superluminescent light emitting diodes (SLEDs) are of increasing interest for a wide range of applications such as optical coherence tomography for which a broadband high power optical source is required. A number of techniques have been discussed to realise a broad optical spectrum, which rely on techniques such as chirped quantum wells [1], or intermixed quantum wells [2]. More recently quantum dot (QD) materials have attracted attention due to their naturally broad emission spectrum from the ground state of the QD [3]. In the present paper we propose and demonstrate a new technique for increasing the emission bandwidth of a QD SLED. Previously we utilised the dot-in-well (DWELL) structure to obtain CW 1.31µm QD lasers exhibiting very low threshold currents.

Device Design, Growth, and Fabrication

The InAs QDs were grown within an InGaAs QW in order to achieve this long wavelength for a GaAs based device. Figure 1 shows the room temperature PL spectra of various samples with differing indium composition within the well showing a smooth variation in wavelength as a function of indium composition. Our new device design relies upon a multi-DWELL structure with different indium compositions within each well. We term these structures dots in compositionally modulated well (DCMWELL) structures.

Two structures are discussed, a DWELL laser structure consisting of 5 $In_{0.15}Ga_{0.85}As$ DWELL active elements, and a DCMWELL structure consisting of 5 wells with indium compositions of 12%, 13%, 13.5%, 14% and 15%. In all other regards, the structures are nominally identical. The active layers were separated by 50nm of GaAs, with the whole separate confinement heterostructure region having a thickness of 400nm. Si and Be doped $Al_{0.4}Ga_{0.6}As$ cladding layers complete the waveguide structure. Further details of the growth are given elsewhere [4]. 15 µm wide shallow ridge structures, mis-oriented by 8 degrees to the crystal facet, were defined by contact lithography and wet chemical etching.

Results

Figure 2 shows normalised electroluminescence spectra for the DWELL and DCMWELL structures. A clear broadening of the emission bandwidth is observed (~40nm to ~60nm). This broadening is in good agreement with modelling of the emission line-shape. Figure 3 shows the light-current response of a 6mm long DCMWELL device. This was obtained using pulsed current injection so as to remove heating effects (1µs pulse at 10 kHz). Output powers of ~3mW per facet are achieved with the experimental set-up limiting the maximum applied current. Figure 4 shows corresponding EL spectra showing further broadening of the emission spectra under increasing current, giving an ~85nm wide emission spectrum at 500mA.

This increase in line-width is attributed to excited state transitions of the QDs.

Conclusions

In summary, we have proposed and demonstrated a new technique to realise broad-band super-luminescent LEDs utilising quantum dots in compositionally modulated wells.

References

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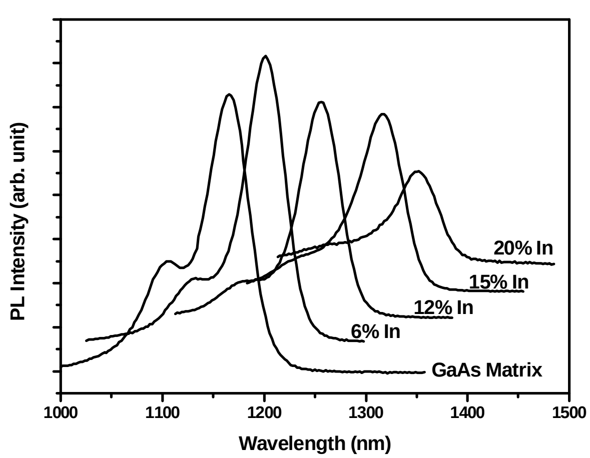

Figure 1. Photoluminescence spectra of DWELL structures as a function of indium composition within the well.

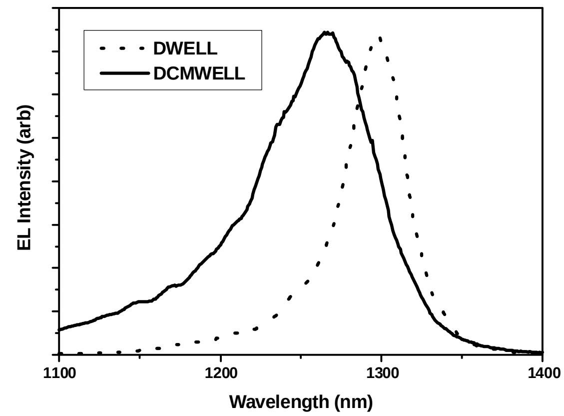

Figure 2. Electroluminescence spectra of DWELL and DCMWELL structuresat a current density of 80A/cm^2.

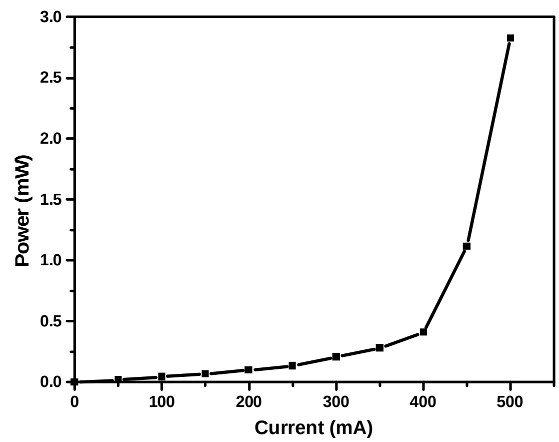

Figure 3. Current-power characteristic for the DCMWELL structure demonstrating superluminence

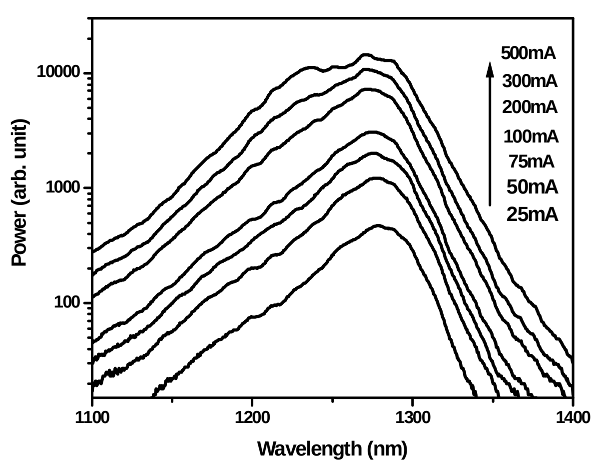

Figure 4. DCMWELL EL spectra as a function of current for a 6mm long device.