1.1-μm broadband superluminescent diodes with height-engineered InAs quantum dots

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Broadband and high power optical sources are essential for medical imaging technologies [1]. Particularly, for optical coherence tomography (OCT) applications, it has been reported that, as compared to the common used OCT light source that operates at 800 nm with relatively narrow bandwidth, using a optical source of 1050nm wavelength considerably improve the imaging resolution and detection sensitivity [2]. The 1000 -1100 nm wavelength range has been proposed and demonstrated to be suitable for the ophthalmic OCT applications due an optimal compromise between water absorption and human tissue scattering. There are few approaches in producing such OCT light source where the most promising one is the use of self-assembled InAs quantum dots as active region in the structure of light emitting diode. Due to their inhomogeneous strain and dots size distribution, multiple layers of InAs/GaAs self-assembled QDs can naturally display wide spectra when used as active region. Emission spectrum with full width at half maximum (FWHM) of 110 nm was reported using 2.5 kA injection current under pulsed mode [3]. For further increasing the bandwidth emission spectra, growth processes such as incorporation of QDs in compositionally modulated quantum wells [4], or use of chirped QD multiple layers [5] have been applied.

In this contribution, broadband superluminescent diodes (SLDs) incorporating multiple layers of InAs quantum dots (QDs) where the dots height was deliberately varied from one layer to another have been grown, fabricated and characterized. The active region of the fabricated QD-SLD structure consisted of two repeats of four layers of InAs quantum dots with GaAs barrier/cap layers, within a 300 nm waveguide. To modify the height of the dots from one layer to another, the formed InAs-quantum dots were first partially covered by a GaAs cap layer grown at low-temperature (485°C). The thickness of this GaAs cap layer was about 2.8 nm, 3.6 nm, 4.5 nm and 6.5 nm for the layer of dots respectively from bottom to top as shown in figure 1. After this partial capping, the dots were further annealed by rapidly raising the temperature to 610°C over 70 s. The *extra* unprotected indium material from the top of the dots was therefore evaporated [6]. Based on transmission electron microscopy (TEM) analysis, the dot's height was estimated to be about 0.2 nm less than the corresponding thickness of the GaAs cap layer grown at low temperature before annealing the dots [6]. The obtained photoluminescence spectrum of such layers of dots is an overlap of four spectra, each of which having a ground-state transition energy position inversely proportional to the average of the dots height in its corresponding layer [6].

The accurate control of the emission energy of each layer of dots by tuning the dots height enabled us to reliability and predictably engineers the bandwidth of the overlapped layers. 3 dB emission bandwidth as wide as 140 nm centered at 1100 nm have been demonstrated from a single device (c.f. figure 2). The achieved output power was about 3 mW at the injection current of 500 mA under pulsed operation.

References:

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Figures:

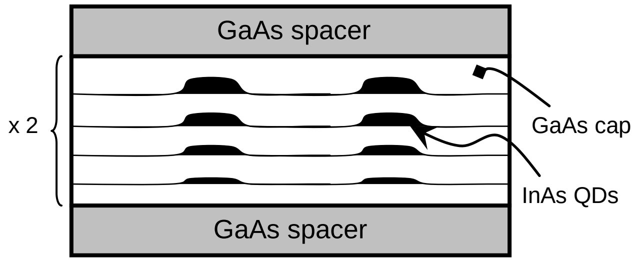

Figure 1: schematic drawing of the active region of the QD-SLD structure.

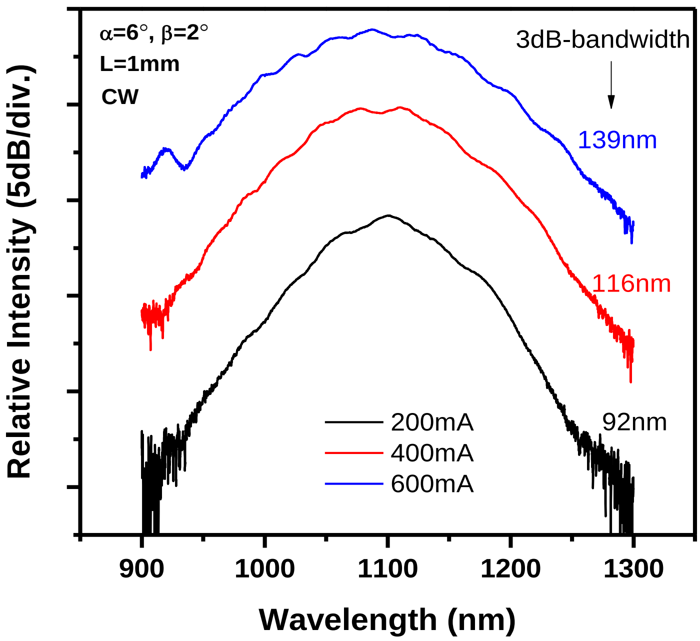

Figure 2: Power spectrum of the QD-SLDs as a function of the CW drive current at 20°C