NTA2022

2nd International Conference on
Nanotechnology: Theory and Applications,
Cairo, 19 – 21 Dec., 2022

Ref. 053

Experimental Characterization of Single and Double Layer InP/AlGaInP Quantum Dot Laser

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KEYWORDS

InP quantum dot laser, vertical stacking of quantum dot layers, semiconductor laser gain, threshold current.

SHORT SUMMARY

In this paper, a comparison between the single-layer and double-layer of InP/ $(Al_{0.1}Ga)_{0.51}InP$ QD laser system fabricated by metal-organic vapor-phase epitaxy is investigated exploring the effects of the additional layer to the threshold current where an increase of the threshold current and output power are recorded and a red shift of the wavelength is observed.

EXTENDED ABSTRACT

Self-assembled quantum dot (QD) has a lot of interesting features such as low threshold current, thermal stability, discrete energy states, and narrow emission lines[1]. The output lasing wavelength of such devices can be controlled by controlling the size of the QD. All these features makes QD lasers suitable for various application like visible light communications [2], and optical sensing [3], where a special attention is given towards the red wavelength lasers. Red wavelength lasers was achieved by the use of InP QDs [4] where a suggestion of the vertical stack providing several advantages such as larger gain [5], A redshift in the lasing wavelength was observed as the number of the stacked layers increases [6].

Experimental setup

The detailed fabrication steps of the QD laser samples under study can be found in [4] where QD were grown by metal-organic vapor-phase epitaxy on an n-doped (100)-GaAs substrate with a misorientation angle of 6° -towards the [111]A direction. The active region is formulated by the deposition of one 2.1 monolayers (ML) of InP QD layers for the single-layer, and two of 2.1 monolayers (ML) of InP QD layers separated by a $(Al_{0.1}Ga)_{0.51}$ InP spacer layer of 4 nm for the double-layer structure that is located inside the two 10-nm $(Al_{0.1}Ga)_{0.51}$InP barrier layers embedded within a 300 nm $(Al_{0.55}Ga)_{0.51}$ InP. Both samples have a chip length of 1.08 mm and a stripe width of 100 µm. The setup in Figure 1 consists of a Newport/ILX Lightwave LDP-38408 pulsed current source with two gold-coated tungsten probes. The double-layer InP/AlGaInP QD laser chip is fixed on a bras base thermally connected to a Lightwave LDT-5910C thermos-electric cooler (TEC) operating at room temperature. A cleaved 100-µm core diameter multimode fibre (MMF) is located on a 5-axis positioner and used to couple the output light from the chip to Yokogawa AQ6370 optical spectrum analyser (OSA) or to Newport 1918 –D power meter (PM). The spectrum resolution is 0.1 nm.

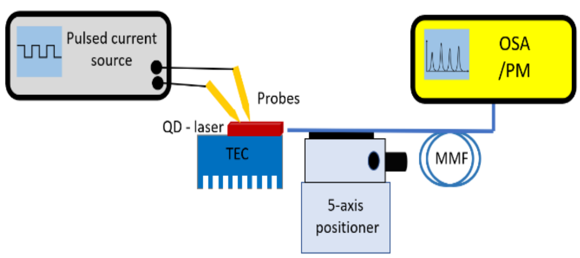
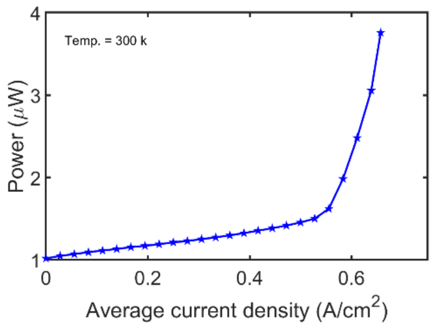


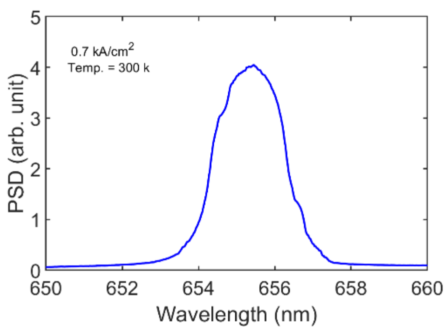
Figure 1 the experimental setup of the QD laser

Results and discussion

In Figure 2 (a) the average output recorded power by the PM is depicted versus the average injected current density for 0.1% duty cycle at room temperature for the single-layer QD laser chip. The relative low output power is due to coupling loss to MM fibre. The QD laser threshold for the single-layer QD laser is evaluated using the linear regression and found to be 0.45 A/cm^2, and slope efficiency is 0.15 W/A. The output spectrum is shown in Figure 2 (b) at average injected current density of 0.7 A/cm^2 where a peak wavelength is 655.4 nm with a FWHM of 2 nm.



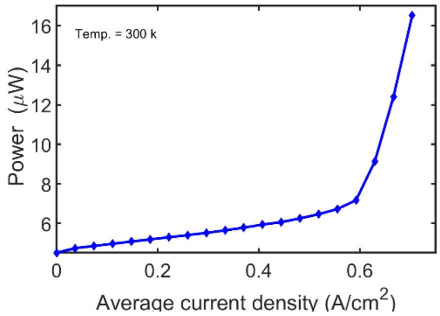
(a)



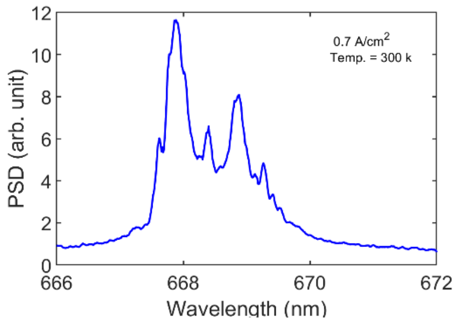
(b)

Figure 2 Single-layer InP/AlGaInP QD laser chip characterization (a) Average output power versus average injected current densities (b) the power spectral density (PSD) vs the wavelength at 0.7 A/cm^2 injected current density.

For the case of double-layer QD laser chip the average output recorded power by the PM is depicted in Figure 3 (a) versus the average injected current density. The extracted threshold is 0.63 A/cm2 resulting in an increase by 40% when compared to the single-layer QD threshold and the slope efficiency is shifted to be 0.2 W/A. Another point to consider is the increase in the collected average power by a factor of 4 compared to the single-layer QD laser chip. The spectrum is shown in Figure 3 (b) for the same average injected current density of 0.7 A/cm^2 as the one for Figure 2 (a). The peak wavelength is shifted to be 667.9 nm with a FWHM of 1.4 nm.



(a)



(b)

Figure 3 Power spectral density (PSD) versus wavelength (a) Average current densities from 0.83 A/cm^2 (b) Average current densities 0.93 A/cm^2 and 0.97 A/cm^2.

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