Experimental Characterization of Multimode Double Layer InP/AlGaInP Quantum Dot Laser

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InP quantum dot laser, multimode laser, semiconductor laser, Inhomogeneous broadening.

SHORT SUMMARY

In this paper, an experimental study is presented for self-assembled double-layer InP/ $(Al_{0.1}Ga)_{0.51}InP$ *QD laser system fabricated by metal-organic vapor-phase epitaxy (MOVPE) with a 4 nm spacer thickness when subjected to a pulsed current source of 0.1% duty cycle at room temperature. The threshold current was found to be 0.63 A/cm² and a closer look at the lasing peak in the spectrum showed the multiple peaks of the system.*

EXTENDED ABSTRACT

Self-assembled quantum dot (QD) laser was first introduced in the late ’80s, where a deposition of a thin layer of the QD material using molecular beam epitaxy (MBE) or MOVPE were proceeded. The resulted strain induced effects helped in the formation of the QD islands due to lattice constant mismatch. The 3-dimensional discreteness gave it an advantage over the bulk and quantum well laser such as low threshold current, and discrete energy states [1].

Red wavelength laser is required in many applications like quantum technology [2]. Double-layer QD laser chip has a lasing wavelength around 666 nm that is rather different from one of the early InP based QD laser chip [3] where the emission of the lasing output was recorded to be around 750 nm. The blue shift can be related to the addition of Al content to the barrier that were needed for better thermal stability as reported in [4]. In this work, an experimental study is presented for self-assembled double-layer InP/AlGaInP QD laser system fabricated by metal-organic vapor-phase epitaxy with a 4 nm spacer thickness. The power versus and current and the spectral characteristics of the laser are examined.

Experimental setup

The double-layer structure and the detailed steps for fabrication process can be found in [4]. The active region is formulated by the deposition of the two of 2.1 monolayers (ML) of InP QD layers separated by a $(\boldsymbol{Al_{0.1}Ga})_{0.51}$ InP spacer layer of 4 nm that is located inside the two 10-nm $(\boldsymbol{Al_{0.1}Ga})_{0.51}$InP barrier layers embedded within a 300 nm $(\boldsymbol{Al_{0.55}Ga})_{0.51}$ InP. The chip length is 1.08 mm and the stripe width is 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 fiber (MMF) is located on a 5-axis positioner and used to couple the output light from the chip to Yokogawa AQ6370 optical spectrum analyzer (OSA) or to Newport 1918 –D power meter (PM).

Results and discussion

In Figure 2 the PM readings of the average output power versus the average injected current density is displayed for 0.1% duty cycle at room temperature. The extracted threshold is 0.63

A/cm^2, while the slope efficiency is 0.2 W/A. The average power measured is relatively low for a chip length of 1.08 mm that can be attributed to the direct coupling loss between the chip and the fibre.

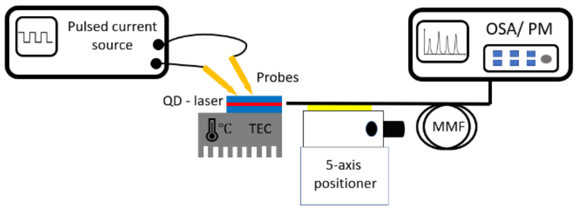

Figure 1 the experimental setup of the QD laser

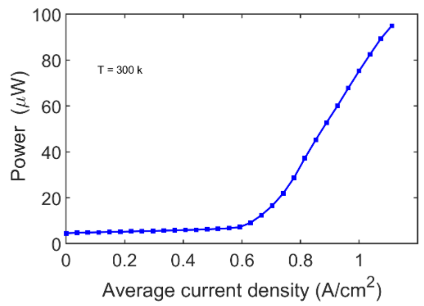

Figure 2 Average output power of the double-layer InP/AlGaInP QD laser chip versus average injected current densities

The chip output spectrum for different excitation average current densities and 0.1% duty cycle as shown in Figure 3 with 2 nm resolution [5]. The operation revealed that the spectrum has a bimodality behavior related to bimodal size distribution of small and large QD group due to fabrication conditions. For low average current densities from 0.46 A/cm^2 to 0.65 A/cm^2, the emission from the large QDs dominates the spectrum. The peak is around 710.7 nm with FWHM 72 nm for 0.46 A/cm^2. As the injected current density keeps on increasing the contribution of the small QD group dominates and the spectral peak is shifted to about 665.6 nm with FWHM 7.34 nm at 0.93 A/cm^2.

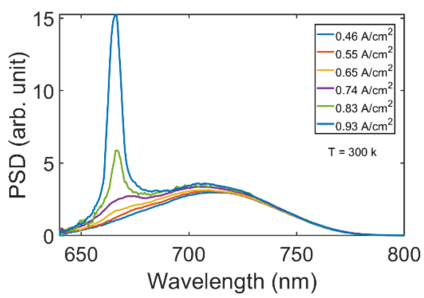

Figure 3 PSD versus wavelength for different current densities from 0.46 A/cm^2 to 0.93 A/cm^2**.**

A fine resolution measurement with 50 pm resolution for the OSA is shown in in Figure 4 (a) for 0.83 A/cm^2 average current density. The spectrum shows the existence of a single dominate peak at 666.3 nm with linewidth of 0.17 nm. In Figure 4 (b) the spectrum is recorded for a higher average current density of 0.93 A/cm^2 and 0.97 A/cm^2 enhancing the multiple peaks in the system where the central wavelength shifts toward lower value at 664.17 nm and 663.93 nm.

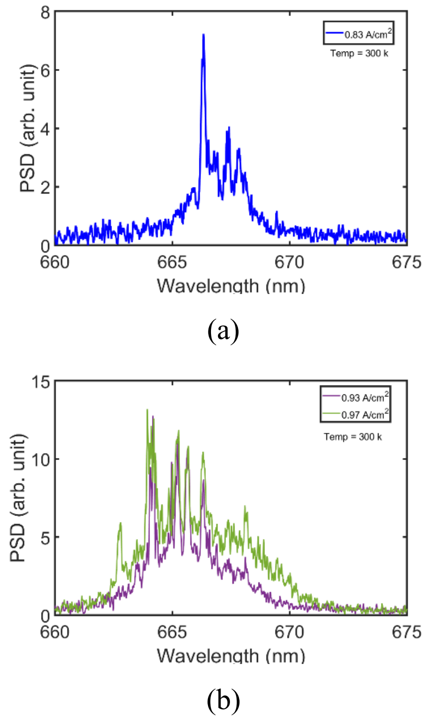

Figure 4 PSD versus wavelength (a) Average current densities from 0.83 A/cm^2 (b) Average current densities 0.93 A/cm^2 and 0.97 A/cm^2.

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