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# 1550 nm InAs QD on InP for VECSEL and MECSEL applications

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**Abstract**—We report on the growth optimization of 1550 nm InAs QD grown on InP substrates used as gain medium within Vertical or Membrane External Cavity Surface Emitting Lasers (VECSEL and MECSEL). High gain structures have been successfully realized. Laser operation at 1520 nm and at room temperature is obtained, high output power (2.2 W) and large wavelength tuning (86 nm) are demonstrated.

**Keywords**—quantum dots; VECSEL; MECSEL

## I. INTRODUCTION

QD nanostructures have been the subject of large interests and studies, as QD fundamental properties such as “0D like” confinement of carriers were very promising for the realization of innovative devices. They have effectively demonstrated superior performances in comparison with commonly used strained quantum wells (SQWs) for the realization of efficient edge emitting lasers (lower threshold, higher characteristic temperature, better mode-locking) [1], and even more recently coherent dual frequency lasers [2]. External cavity surface emitting lasers, such as VECSELs and MECSELs enable to get very high output power, wavelength tunability and close to ideal beam quality [3]. Combining such V(M)ECSEL structures with QD active layer structures is thus very attractive, but it still represents a great challenge as QD present an inherent lower effective gain in comparison with SQWs. For this reason, most results have been obtained with the steadiness InAs/GaAs QDs material, limiting the wavelength emission up to 1.3  $\mu\text{m}$  [4]. In this work, we present recent achievements we obtained in reporting 1550 nm InAs/InP QD VECSEL and MECSEL operation, as a direct consequence of the QD growth optimizations.

## II. QD VECSEL AND MECSEL RESULTS

InAs QDs have been grown by gas source molecular beam epitaxy, on InP(311)B substrate. Growth optimization has been conducted, in order to promote a high modal gain. It involves the growth of a very high QD density ( $10^{11} \text{ cm}^{-2}$ ) and a stacking of QD layers using reduced thickness barriers (15 nm) while maintaining a high optical efficiency and a controlled emitted wavelength. The results of these growth optimizations are shown in Fig.1(a) and (b). A structure containing 4x5 QD layers has been designed, grown and integrated in a VECSEL and a MECSEL structure. The VECSEL structure includes the QD active layer, a wafer fused AlAs/GaAs distributed Bragg reflectors (DBR), and a top diamond heat spreader (Fig.2(a)). The MECSEL structure is characterized by the same QD active layer, inserted between two SiC heat spreaders. Both structures have been measured in external cavities with typical 40-60 cm long cavity, with high reflectivity mirrors ( $\sim 99.8\%$ ), excited with a 200  $\mu\text{m}$  in diameter optical pump at 980 nm. As shown in Fig.3(a), a high output power of 2.2 W is obtained with the QD VECSEL chip, mainly attributed to the high thermal spreading efficiency of both the DBR mirrors and the diamond heat spreader [5]. For the QD MECSEL device; lower output power is achieved (300 mW, not shown) mainly limited by the lower thermal conductivity of the SiC heat spreaders. In the latter case, the absence of the DBR and its limited reflectivity bandwidth enables a wide tuning of the MECSEL wavelength as high as 86 nm, as shown by Fig.3 (b) [6]. Both results present first demonstrations of 1550 nm QD based VECSELs and MECSELs.

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1. D. G. Deppe, et al “Quantum dot laser diode with low threshold and low internal loss”, Electron. Lett. vol 45 ,pp 54, n°1, 2009
2. K. A. Federova et al, “Compact all-quantum-dot based tunable THz laser source”, IEEE Journ. Select. Topics Quant. Elect. Vol 23, n°4, pp 1900305, 2017
3. H. Kahle et al, “Semiconductor membrane external-cavity surface-emitting laser (MECSEL)”, Optica, Vol. 3, n° 12, 2016.
4. A. A. Nakdali et al, “High-Power Quantum-Dot Vertical-External-Cavity Surface-Emitting Laser Exceeding 8 W”, IEEE Photon . Technol. Lett. Vol 26, n°15, pp 1561, 2014.
5. K. Nechay et al, “High power InAs quantum dot VECSEL emitting at 1.5  $\mu\text{m}$ ”, Applied Physic Letters vol 115, p 171105, 2019.
6. H.-M. Phung et al, to be submitted.

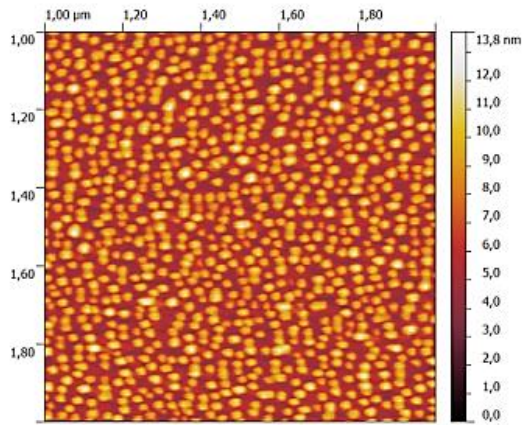


Fig. 1.  $1 \times 1 \mu\text{m}^2$  AFM image of a single QD layer

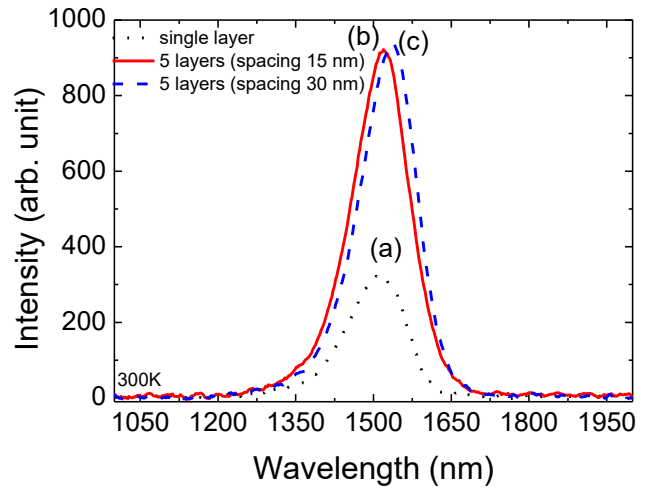


Fig.2 : Photoluminescence spectra of a single QD layer (a), five QD layers with a 30 nm spacing (b) and 15 nm spacing (c).

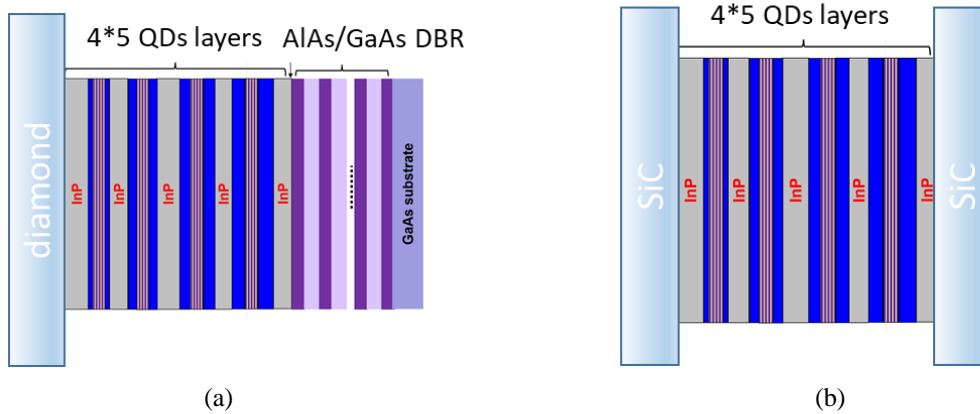
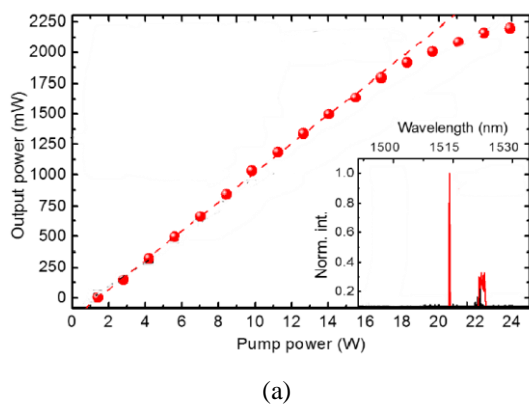
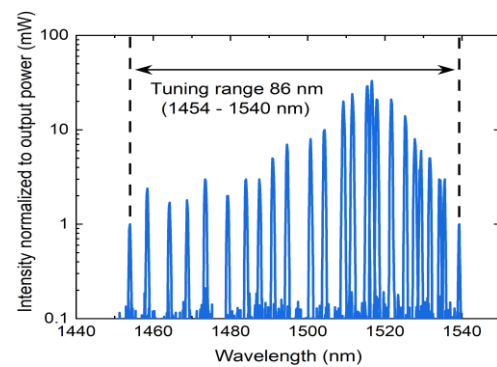


Fig. 3 : Schematic structures of the QD based VECSEL(a) and MECSEL(b)



(a)



(b)

Figure 4 : Output power of the QD VECSEL (a) and wavelength tuning of the QD MECSEL(b), measured at  $15^\circ\text{C}$