

Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser on InP

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Anisotropic gain media like quantum dash-based active regions have already shown interesting optical properties such as high polarized emitted light and wide spectral coverage in micrometer-long Vertical-Cavity Surface-Emitting Lasers (VCSELs) [1,2]. The use of mm-long external cavities can provide additional advantages such as high power level, narrower linewidth emission and new functionalities by using intra-cavity elements. Here, we report on an Optically-Pumped InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser (OP-QDH-VECSEL) on InP. The active region of the OP-QDH-VECSEL has been grown by Gas Source Molecular Beam Epitaxy on a (001)-oriented InP substrate and consists of 3 sets of 6 InAs QDH layers, surrounded by 15 nm thick $\text{Ga}_{0.2}\text{In}_{0.8}\text{As}_{0.435}\text{P}_{0.565}$ barriers and InP spacers, in a Resonant Periodic Gain configuration [1]. A 17-pairs GaAs/Al_{0.97}Ga_{0.03}As Distributed Bragg Reflector has been metamorphically grown on the bottom of the structure, completed by a gold layer. The structure has been then metallicity bonded onto a CVD-grade diamond substrate in a flip-chip configuration and fixed onto a temperature-controlled copper heat-sink [3]. Finally, the InP substrate has been removed, and a SiN_x anti-reflection (AR) coating at the emission wavelength (around 1.6 μm) has been deposited on the top surface. Fig. 1(a) shows the chip architecture and the calculated standing wave inside the structure. A 2x2 μm² AFM image of an uncapped InAs QDH plane is shown in inset. The OP-QDH-VECSEL has been tested in the cavity setup presented in Fig. 1(b). Initially, the chip has been placed in a 12-mm-long cavity (5-mm-radius of curvature output mirror with R=99.5% at the emitted wavelength) with no etalon inside the cavity and pumped by a 980 nm multi-mode fibered semiconductor laser, with an elliptical pump spot of 145 μm x 210 μm. In such conditions, the OP-QDH-VECSEL was able to deliver up to 163 mW at T=20°C (pump-limited), with a multimode emission in the 1615-1628 nm range, as shown in Fig. 2(a). The OP-QDH-VECSEL has been subsequently forced to oscillate in a single-frequency regime. To this aim, a single-mode 980 nm fibered semiconductor DFB laser with an elliptical pump spot of 80 μm x 120 μm has been used to pump the active medium, and the cavity length has been set to 49 mm (output coupler of 50 mm-radius of curvature and R=99.5%). Finally, a 40 μm thick fused silica etalon with R=30% on both faces has been inserted inside the VECSEL cavity. With such a configuration, an emitted power of 7.9 mW (limited by the pump) has been obtained at T=19.5°C with a single-mode emission centered at 1610 nm (see Fig. 2(b)). According to the QDH alignment, the emission is linearly polarized along the [1-10] crystallographic direction, with a measured orthogonal polarization suppression ratio of 23 dB (Fig. 3(a)). An estimation of the laser linewidth has been done by a delayed self-heterodyne measurement, which gives a laser linewidth of 22 kHz (Fig. 3(b)). Further characterizations in low-noise external cavity configuration are underway.

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- [1] J. M. Lamy et al., Applied Physic Letters **95**, 011117 (2009).
 [2] F. Taleb et al., IEEE Photonics Technology Letters **25**, 2126-2128 (2013).
 [3] Z. Zhao et al., Optics Letters **36**, 4377-4379 (2011).

Figures

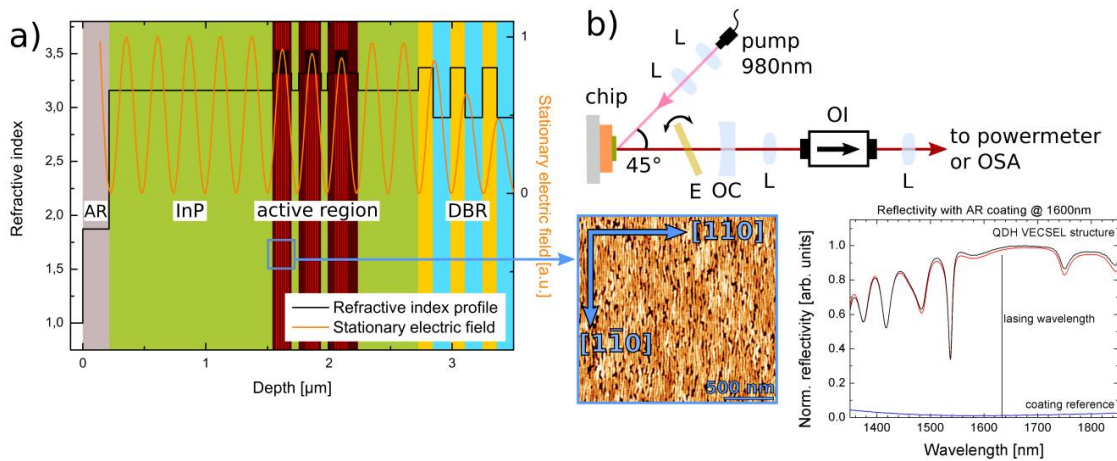


Fig. 1: (a) design of the OP-QDH-VECSEL chip and computed standing wave inside the structure. (b) cavity setup used during characterizations (insets: $2 \times 2 \mu\text{m}^2$ AFM image of an uncapped plane of QDH aligned along [1-10] crystallographic axis and sample surface reflectivity after AR coating deposition).

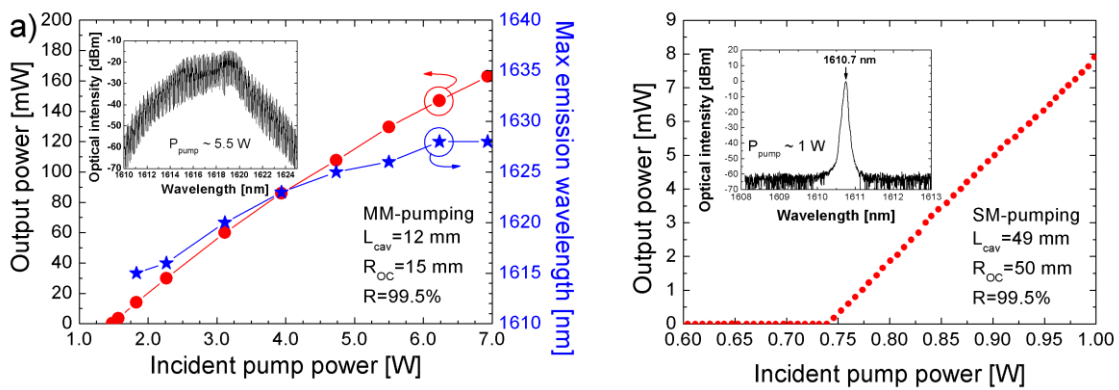


Fig. 2: (a) multi-mode and (b) single-mode output characteristics (optical spectra in inset).

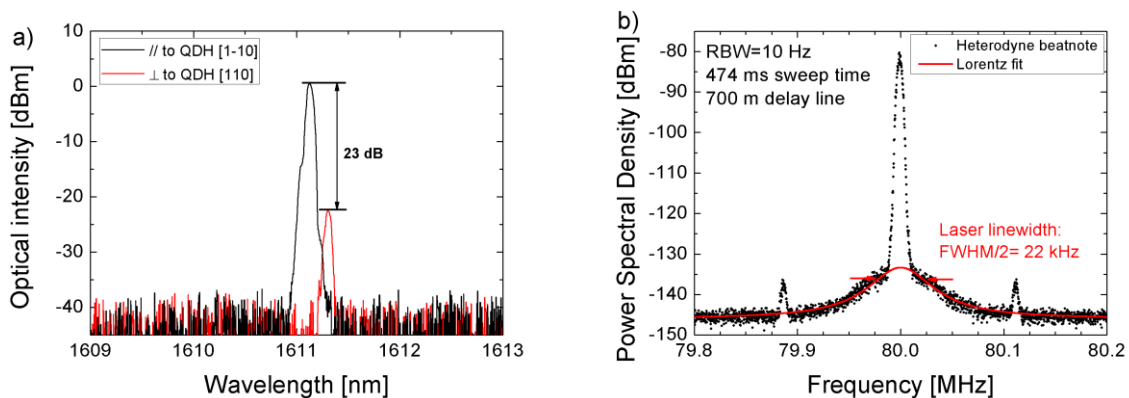


Fig. 3: (a) polarization resolved single-mode spectra and (b) delayed self-heterodyne linewidth measurement ($f_{\text{AOM}}=80 \text{ MHz}$, $L_{\text{delay}}=700 \text{ m}$, 470 ms sweep time and 10 Hz RBW).