

Class-A Operation of InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser

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Abstract: InAs Quantum Dash-based Vertical-External-Cavity Surface-Emitting Laser on InP is demonstrated. Up to 163 mW and 7 mW have been obtained in multi-mode and single-mode operation, respectively. Class-A behavior is demonstrated on such device.

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Since their first demonstration in 1997 [1], Vertical-External-Cavity Surface-Emitting Lasers (VECSELs, also known as Semiconductor Disk Lasers, SDLs) have gained much attention. They can be used in numerous applications, ranging from optical sensing, frequency doubling, ultrafast photonics, high resolution spectroscopy and microwave photonics. Beside their high power and good quality circular beam, VECSELs offer the advantage to use intra-cavity optical elements (non-linear crystals, saturable absorbers, etalons, etc.) to further extend their functionalities. Moreover, VECSELs have been demonstrated to operate in the so-called Class-A regime (free of relaxation-oscillations phenomena), provided that the cavity is long enough [2]. In such a regime, VECSELs show extremely low Relative Intensity Noise (RIN) levels, down to the shot-noise. On the other hand, quantum dash-based active media have been demonstrated to ensure a stable state of polarization of the emitted light [3,4], together with a wide material gain [5] and a lower sensitivity to temperature. The original integration of such an active region into a VECSEL configuration is thus expected to extend existing functionalities and to open the way to new ones.

Here we present preliminary results on an optically-pumped InAs quantum dash-based VECSEL (OP-QDH-VECSEL) on a (001)-oriented InP substrate, emitting in the telecom L-band (around 1619 nm). In the following, the laser structure is described. The multi-mode output power characteristic and optical spectrum are presented. Class-A operation of the laser is finally demonstrated. To the best of our knowledge, this is the first experimental demonstration of a QDH-VECSEL on InP.

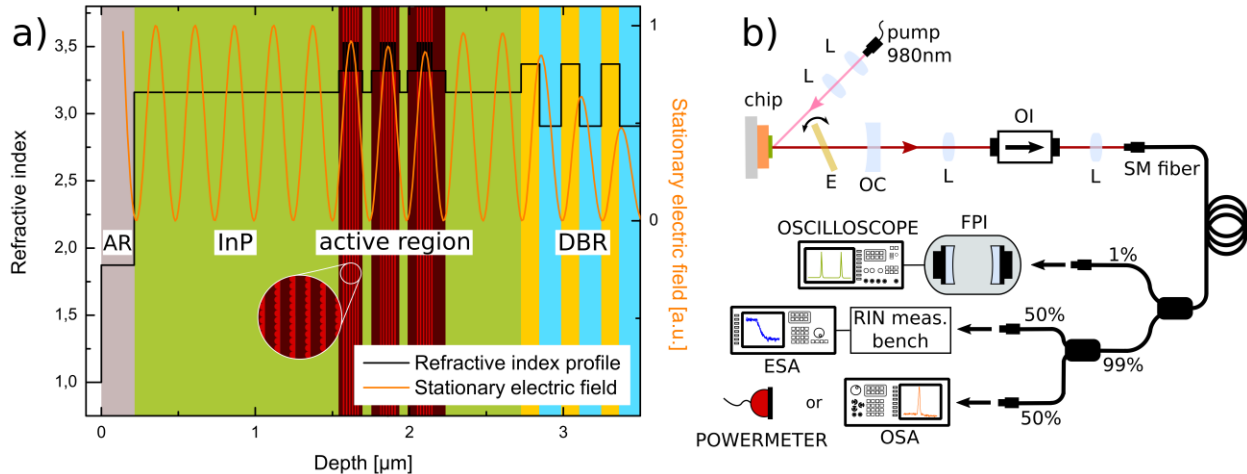


Fig. 1: a) OP-QDH-VECSEL design and computed stationary electric field inside the structure; b) experimental setup. L: lens, E:etalon, OC: output coupler, OI: optical isolator, FPI: Fabry-Perot interferometer, ESA/OSA: electrical/optical spectrum analyzer.

Fig. 1a shows the detailed structure of the QDH-VECSEL. The active region has been grown by a gas-source MBE system on a (001)-oriented InP substrate. It consists of 3 sets of 6 planes of self-assembled InAs quantum dashes placed on the antinodes of the stationary electric field (Resonant Periodic Gain configuration). Each QDH

plane is surrounded by $\text{Ga}_{0.2}\text{In}_{0.8}\text{As}_{0.435}\text{P}_{0.565}$ barriers to ensure the carrier confinement and to enhance the pump absorption. The bottom Distributed Bragg Reflector (DBR) consists in 17 periods of $\text{GaAs}/\text{Al}_{0.97}\text{Ga}_{0.03}\text{As}$ layers, which has been metamorphically grown on the InP-based structure, completed with a gold metallic layer (not shown in the figure). After metallic bonding onto a CVD diamond host substrate, the InP substrate has been removed and the whole structure has been fixed to a temperature-controlled copper thermal sink [6]. A SiN_x anti-reflection coating at the emission wavelength has been added on the top surface.

The sample has been tested in the cavity set-up shown in Fig. 1b. The output power characteristic and the spectrum presented in Fig. 2a were obtained using a multi-mode 980 nm semiconductor laser pump with a $145\ \mu\text{m} \times 210\ \mu\text{m}$ spot, and the QDH-VECSEL was operating in the multi-mode regime. The cavity length was set to 12 mm and no etalon was inserted inside the laser cavity. Under these conditions, a fundamental mode diameter of $\sim 120\ \mu\text{m}$ on the chip surface was estimated. Up to 163 mW output power at $T=20^\circ\text{C}$ has been obtained for an incident power of 7 W (pump limited), with an emission centered at 1619 nm.

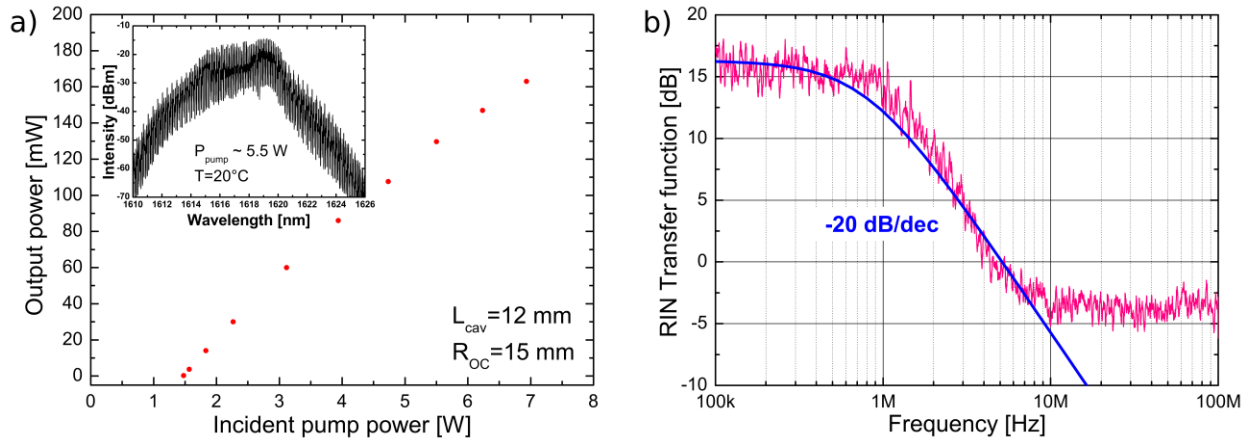


Fig. 2: a) output power characteristic and optical spectrum (inset) of the QDH-VECSEL in multi-mode operation ($T=20^\circ\text{C}$, radius of curvature of the output coupler is 15mm). b) RIN transfer function of the laser (obtained for $I_{ph}=2\text{mA}$).

In order to obtain the Class-A regime for the QDH-VECSEL, we optimized the setup in terms of noise by using a single-mode semiconductor pump laser (980 nm, pump spot of $80\ \mu\text{m} \times 120\ \mu\text{m}$), extending the laser cavity up to 49 mm ($R_{OC}=50\ \text{mm}$) and adding a $40\ \mu\text{m}$ thick fused silica etalon with $R=30\%$ on both faces, to ensure the longitudinal single-mode operation of the QDH-VECSEL (checked with a Fabry-Perot interferometer). In such conditions, the laser emits 7 mW at 1610 nm when pumped at 1 W. We acquired the RIN spectra of both QDH-VECSEL and pump with a dedicated RIN measurement bench composed by a InGaAs fast photodiode, two RF amplifiers and an ESA. A shot-noise level value of $-158\ \text{dB/Hz}$ has been obtained for our QDH-VECSEL, for a detected photocurrent of 2mA. The RIN transfer function, after pump normalization, is given in Fig. 2b: it shows that the QDH-VECSEL acts like a 1st order filter with a cut-off frequency of about 800 kHz and a slope of $-20\ \text{dB/dec}$, which confirms the Class-A behavior.

Further characterization are underway, in order to investigate quantum dash-based active medium properties in low-noise external cavity configuration.

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