

## 1.55 $\mu\text{m}$ VCSEL polarization controlled with quantum wells / quantum dashes hybrid active layers.

L. Chaccour<sup>1</sup>, L. Bramerie<sup>1</sup>, C. Levallois<sup>1</sup>, N. Chevalier<sup>1</sup>, S. Trebaol<sup>1</sup>, M. Alouini<sup>1</sup> and C. Paranthoen<sup>1</sup>

<sup>1</sup>Univ Rennes, INSA Rennes, CNRS, Institut FOTON – UMR 6082, F-35000 Rennes, France

[cyril.paranthoen@insa-rennes.fr](mailto:cyril.paranthoen@insa-rennes.fr)

The deterministic control of output polarization state has always appeared as a detrimental property of VCSEL devices, mostly related to the isotropic nature of such lasers. Indeed, VCSEL are characterized by a circular geometry, integrating most of the time efficient active layers such as strained quantum wells (SQW) presenting almost similar gain according to the main crystallographic orientations. As the consequence, while operating in CW or under modulation, such VCSELs usually present unpredictable oscillation along  $[110]$  or  $[1-10]$  crystallographic orientations, with instabilities and/or switching, leading to errors in data transmission, in particular when polarization dependent optical components are used in the optical transmission line. Several methods have been proposed to ensure a stable and predictable output polarization by introducing some spatial or loss anisotropy: elliptical geometry, grating defined on the output mirror, and more recently by using high contrast grating mirrors. Recently, we have proposed an alternative approach limiting this complexity in the VCSEL processing by using elongated quantum nanostructures (quantum dashes (QDH)) to bring controlled gain anisotropy [1]. We have shown an effective control in VCSEL and VECSEL output polarization at  $1.62 \mu\text{m}$ . This wavelength was higher than the  $1.55 \mu\text{m}$  targeted lasing wavelength, mainly due to the growth process of such 1D QDH nanostructures which are highly strained and formed spontaneously, making it difficult to manage at the same time high gain and a specific wavelength. To overcome this drawback, we realize in this work a  $1.55 \mu\text{m}$  hybrid VCSEL, combining SQW and QDH.

The Fig. 1 presents the photoluminescence spectra of 6 SQW (black) and 6 QDH (red) layers separately grown on InP substrates. SQW emission is centered at  $1.52 \mu\text{m}$  and unpolarized, whereas QDH emission is more likely centered at  $1.57 \mu\text{m}$  but polarized according to  $[1-10]$  direction. From these quantum nanostructures two optically pumped VCSEL structures including two dielectric DBRs have been fabricated with the same process. These two VCSELs differ mainly by the nature of the active layer. The first one consists in 9 SQW distributed over the three electrical field nodes presenting the same pumping efficiency (3/3/3 SQW) (labeled as SQW-VCSEL), and the second one consists in 6 SQW and 6 QDH distributed over the same three electrical field nodes (3 SQW/3SQW/6 QDH) (labeled as hybrid-VCSEL). Both VCSELs are optically pumped with a CW SMF polarization controlled laser diode at  $980 \text{ nm}$ . The VCSEL output polarization states have been simultaneously monitored on two crossed polarization photodiodes. As shown on Fig. 1, and 2 both VCSELs exhibit CW operation at room temperature, with a wavelength centered at  $1540 \text{ nm}$ , even if the QDH maximal gain is expected to be redshifted close to  $1.6 \mu\text{m}$  considering the photoluminescence emission at  $1.57 \mu\text{m}$ .

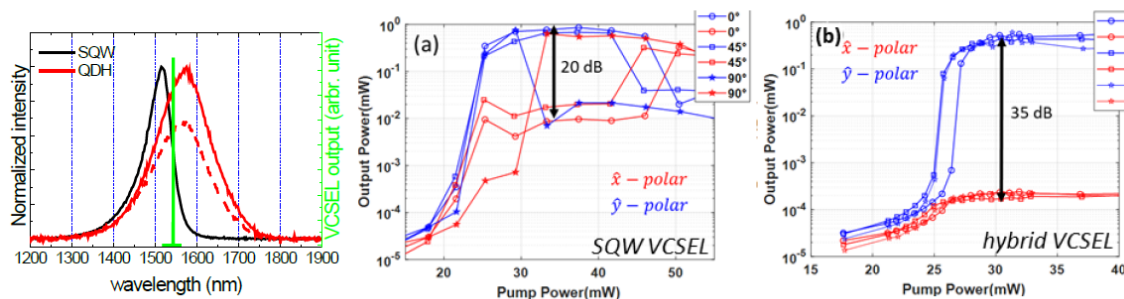


Figure 1 : Photoluminescence of the SQW and QDH. The green line is the typical lasing emission of both VCSELs

Figure 2 : VCSEL polarization resolved output power as function of input power, and for different linear polarization of the input pump for the SQW VCSEL (a) and the hybrid VCSEL (b).  $\hat{x}$  and  $\hat{y}$  are orthogonal polarizations close to  $[110]$  and  $[1-10]$

Fig. 2 represents the VCSELs output power when the polarization is resolved for various pump linear polarization orientations. As commonly observed in VCSELs our SQW VCSEL exhibits important polarization instabilities and polarization switching. Conversely, in the case of the hybrid VCSEL, the polarization is stable and aligned with the QDH orientation. Moreover, the pump power and its polarization orientation do not affect the laser polarization. It must be noted that the 35 dB polarization ratio we measure is limited by the polarization extinction of the beam splitter we used). In conclusion we have shown that the combination of QDH with SQW in VCSEL active layers, enable to benefit simultaneously from the high gain of SQW and from the gain anisotropy of QDH to realize wavelength and polarization controlled VCSELs.

This work is supported by HYPOCAMP ANR-ASTRID project (grant ANR-14-ASTR-0007-01)

[1] S. Pes et al, "Class-A operation of an optically-pumped  $1.6\mu\text{m}$ -emitting quantum dash-based vertical-external-cavity surface-emitting laser on InP," Optics Express. Vol. 25 (10), pp. 11760-11766 (2017)