Optical mode control in long-wavelength vertical-cavity surface-emitting lasers

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Vertical-cavity surface-emitting lasers (VCSELs) with a spectral emission in the "long"-wavelength regime (between 1.3 µm and 1.6 µm) are very suitable for applications in long-distance optical communication and in gas sensing. They possess unique properties, such as a very low threshold current, an emitted beam with a circular profile and the capability to be tested on wafer. These make them highly competitive as compared to more conventional edge-emitting semiconductor lasers. However, several drawbacks limit the applications of the VCSEL technology: multiple transverse modes may be sustained by their cavity, leading to different emission wavelengths and to polarization instabilities. Therefore, more efficient and reproducible designs that could be implemented in a large volume are still needed. The performance of long-wavelength VCSELs is also limited by the relative enhancement of non-radiative recombination processes [1]. This talk presents a novel technological approach that has recently been demonstrated for increasing the power emitted in single-mode from a long-wavelength VCSEL [2]. It consists of an additional processing step, where an air gap pattern is etched directly inside the laser cavity. A significant number of devices with varying pattern shapes and dimensions were investigated by on-wafer mapping. This led to the identification of a pattern design that statistically increases the maximal single-mode emitted power by about 30% relatively to unpatterned VCSELs. Numerical simulations [3] based on a calibrated and self-consistent fully three-dimensional electrical, thermal and optical computational model support these observations. They also predict optimized pattern dimensions, for which higher-order transverse modes are localized out of the current aperture, with negligible penalty on the threshold and emitted power of the fundamental mode [4].

Keywords:
Vertical-cavity surface-emitting lasers (VCSELs), clean-room processing, programming and characterization, single-mode emission, numerical simulations, laser dynamics, Auger recombination.

References:

[1] Volet and Kapon, Appl. Phys. Lett. **97**, 131102 (2010).
[2] Volet, Czyszanowski, Kapon *et al.*, Opt. Express **21**, 26983 (2013).
[3] Czyszanowski, Volet, Kapon *et al.*, IEEE J. Sel. Topics Quantum Electron. **19**, 1702010 (2013).
[4] Czyszanowski, Volet, Kapon *et al.*, in preparation for IEEE J. Sel. Topics Quantum Electron.

Biography:

Nicolas Volet received the B.Sc. and M.Sc. from EPFL, Switzerland in 2007 and 2009, respectively. In 2006-2007 he was selected for a one-year exchange program at Carnegie Mellon University in Pittsburgh (PA). In 2008-2009, he was involved in the simulation and characterization of solar cells based on quantum confinement at the University of Houston (TX). He received his PhD in early 2014 from EPFL, on the optical mode control in long-wavelength VCSELs. A major achievement of this thesis work consists of the demonstration of a novel and reproducible technology for enhancing the single-mode power emitted from these devices.