Progress and applications of VECSELs: the most versatile laser platform

M. Guina
Optoelectronics Research Centre, Tampere University of Technology, Korkekoulunkatu 3, Tampere 33720, Finland, http://www.tut.fi/orc

Vertical-external-cavity surface-emitting lasers (VECSELs), also referred as semiconductor disk lasers (SDLs), have emerged at the frontier between solid-state and semiconductor laser technologies. Therefore, these high-brightness light sources draw important advantages from both semiconductor and solid-state lasers: the simplicity to engineer the emission properties of semiconductors is combined with the functionality of solid-state lasers owing to the use of external cavity architectures. This combination has enabled obtaining outstanding results in terms of wavelength coverage (from visible to mid-IR), high-power (100W-level), single-frequency operation, efficient intracavity frequency conversion, and ultra-short pulse generation (down to sub-picosecond range with GHz repetition rate). Moreover, the low-cost of broad-area diodes used to pump the VECSELs and the broad-band pump absorption, have made the optically-pumped-VECSELs practical and cost effective.

The presentation aims at introducing the technological concepts underpinning VECSEL developments, in connection with main milestones that have marked the emergence of this laser technology. In particular, it focuses on presenting our achievements concerning wavelength extension of mode-locked VECSELs towards visible part of the optical spectrum (675 nm) by using GaInP/AlGaInP/GaAs hetersotructures, and towards the mid-IR (2 μm) by using InGaSb/GaSb quantum-wells. For mode-locking we have used novel semiconductor saturable absorber mirrors (SESAMs) that are also introduced. Furthermore, the development of VECSELs emitting yellow-orange radiation with a record power of more than 20 W is highlighted. We note here that the yellow-orange spectral range cannot be reached via direct emission from semiconductors, yet such lasers would be ideal for applications in bio-photonics owing to high-absorption in hemoglobin.

VECSEL developments have been fostered by the need to attain unique combination of output parameters for applications in spectroscopy, laser cooling, laser projection, life-science, or microscopy, while using an affordable and compact laser platform. Future development steps towards achieving a high application impact are discussed in connection with technological requirements, for example linked to fabrication of specific semiconductor heterostructures.