The faculty of Engineering of the Vrije Universiteit Brussel and the faculty of Engineering and Architecture of the Universiteit Gent invite you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES (VUB°
DOCTOR OF PHOTONICS ENGINEERING (UGENT)

of **Salah Eddine Guessoum**

The public defense will take place on **Tuesday 30th June 2026 at 4pm** in room **D.2.01** (Building D, VUB Main Campus)

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A DUAL STUDY OF OPTICALLY INJECTION-LOCKED, STRAIN-VCSELS AND SIGNAL MODULATION NEAR POLARIZATION SWITCHING

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Abstract of the PhD research

Vertical-Cavity Surface-Emitting Lasers (VCSELs) are compact, energy-efficient sources widely deployed in short-reach communication systems. However, as the demand for dense wavelength-division multiplexing (DWDM) and high-speed modulation continues to rise, there is a need to enhance their wavelength control and polarization dynamics. Among the emerging strategies, optical injection locking (OIL) has proven effective in improving laser stability, linewidth, and frequency tunability, while mechanical strain provides a compact and reversible method for tailoring the lasing wavelength and birefringence of VCSELs.

In this thesis, I explore the use of mechanical strain and optical injection locking (OIL) as combined tools for enhancing VCSEL performance. Strain engineering is employed to achieve tunable and reversible wavelength shifts, as well as to modify the internal birefringence of the device. Optical injection locking further sharpens the spectral response, enabling mode control, and enhancing the VCSEL's suitability for multi-channel DWDM operation. The interplay between strain-induced wavelength tuning and OIL is leveraged to realize equally spaced, stable emission channels which is essential for scalable photonic networks.

Interestingly, mechanical strain can also place the laser into regimes where polarization switching (PS) occurs. To better understand the laser's behavior in this critical region, I conduct a detailed numerical investigation using the Spin-Flip Model (SFM), focusing on the response of the VCSEL to a sinusoidal current modulation near the PS threshold. This study reveals a rich variety of dynamical regimes—including periodic polarization oscillations, bistability, and modulation suppression—depending on modulation parameters. These insights are key for understanding the limits and opportunities of polarization-based modulation in strained VCSELs.

Overall, the thesis presents a comprehensive study of strain-tunable, injection-locked VCSELs, from wavelength stabilization and DWDM compatibility to polarization dynamics near switching, offering valuable tools for next-generation optical interconnects and all-optical signal processing.