VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Mohammadshahab Abdollahi**

The public defense will take place on **Thursday 24th April 2025 at 2pm** in room **D.2.01** (Building D, VUB Main Campus)

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OPTICAL INJECTION IN ON-CHIP INP MULTI-WAVELENGTH LASERS AND ITS USE FOR ALL OPTICAL SIGNAL PROCESSING

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Abstract of the PhD research

Semiconductor lasers subject to optical injection display a wide range of dynamical behavior, including stable locking, periodic oscillations, and chaos. The utility of injection locking in improving laser performance, such as reducing linewidth, suppressing mode hopping, and enhancing modulation bandwidth, has been extensively explored. Outside the locking range, different types of dynamics emerge which have been used in various applications such as THz signal generation, chaotic communication, and random bit generation.

While single-mode semiconductor lasers effectively deliver a consistent beam of light, they struggle to meet the diverse wavelength needs or support simultaneous operation at multiple wavelengths required by many applications. This is where multi-wavelength lasers (MWLs) come into play. In recent years, MWLs have gained significant interest as they may be key enablers of new and innovative applications. Multi-wavelength lasers (MWL) are devices designed to emit multiple and controllable modes thereby enabling tailored and reconfigurable functionalities. Over the last years, several types of MWL sources have been demonstrated, either by combining multiple single wavelength lasers with, e.g., an arrayed waveguide grating, or by designing lasers that are inherently multimode such as quantum-dot lasers, modelocked lasers, or distributed Bragg reflector (DBR) lasers. In particular, DBR-based MWL lasers stand out because of their simplicity principle to control and switch the emitted modes of the laser. When combined with optical injection, the additional wavelengths in multi-wavelength lasers add a new degree of freedom and new features. Exploiting such features in multi-wavelength lasers could unlock new dynamical regimes allowing, e.g., THz generation or advanced all-optical processing applications.

In this thesis, I experimentally and numerically analyze the impact of different types of optical injection ranging from CW laser injection to more complex modulated optical injection on the behaviour of the injected and un-injected modes of our on-chip DBR-based multi-wavelength laser. In addition, given the significant separation between the cavity modes of our MWL which can extend up to 10 THz, together with the strong intermodal coupling between different longitudinal modes of our MWL, I enabled several innovative schemes, including: Spectral multiplication of a narrowband frequency comb spanning from few GHz to 1.3 THz, All optical THz signal filtering, and Frequency up conversion of a signal employing ASK modulation.