



Topic of dissertation thesis

Academic year 2026/2027

Title	Multi-domain photonic device engineering for hybrid silicon-compatible integrated circuits		
Institute	Faculty of Electrical Engineering and Information Technology University of Žilina		
Place	Žilina, Slovakia		
PhD. programme	telecommunications		
Supervisor	Ing. Daniel Benedikovic, PhD. Department of multimedia and information-communication technology		
Co-supervisor	NA		
Study form	Internal		
Study duration	3 years (internal form)		
Study language	Slovak, English		
Start date	1.9.2026		
Research domain	Integrated photonics; Hybrid integration, Silicon nitride; Device design		
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Dissertation topic abstract

This PhD thesis focuses on the engineering of multi-domain photonic devices for hybrid silicon-compatible integrated circuits based on silicon, silicon nitride, and heterogeneous material stacks. The research targets scalable, low-loss, and broadband components capable of simultaneous wavelength, modal, and polarization control within unified device architectures. Emphasis is placed on compact, fabrication-tolerant solutions supporting high-speed communications, sensing, and quantum applications. By combining advanced numerical modeling, inverse design methodologies, and experimental validation, the work aims to establish interoperable multi-functional photonic building blocks enabling flexible, high-performance, and application-agnostic integrated photonic systems.

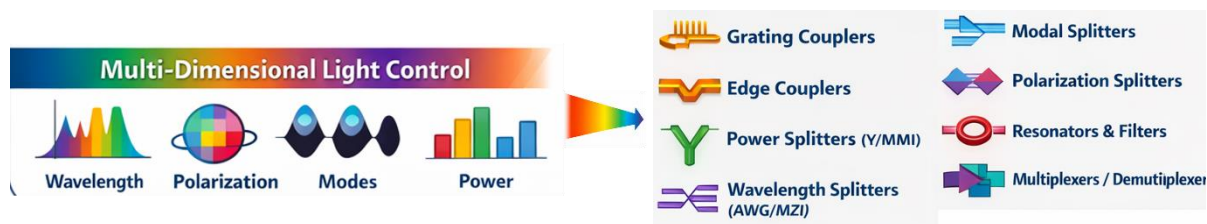
Extended information, research responsibilities and tasks of PhD. candidate

The rapid evolution of photonic integrated circuits (PICs) is driven by the growing performance requirements of high-speed optical communications, advanced sensing platforms, and emerging quantum photonic technologies. Although integrated photonics has established itself as a leading platform for scalable integration, most existing device implementations remain application-specific and optimized for a single operational domain. This limits interoperability across wavelength bands, polarization states, spatial modes, and functional regimes. The increasing complexity of hybrid material stacks and heterogeneous integration further amplifies the need for unified, multi-domain design strategies capable of ensuring broadband operation, low loss, fabrication tolerance, and cross-application compatibility.

This PhD research aims to advance multi-domain photonic device engineering for hybrid silicon-compatible PICs based on silicon (Si), silicon nitride (Si_3N_4), and heterogeneous material platforms. The objective is to develop compact, scalable, and fabrication-robust photonic devices capable of simultaneously addressing wavelength-division multiplexing, polarization diversity, and mode-division multiplexing within unified architectures. Besides the development of individual components, the work seeks to establish interoperable building blocks enabling seamless integration across multiple application domains.

The research will encompass passive routing structures and hybrid functional elements for advanced on-chip management of light sources. Particular emphasis will be placed on broadband

performance, minimized insertion loss, low crosstalk, high extinction ratio, and tolerance-aware design compatible with foundry fabrication constraints.



The methodological framework integrates advanced numerical modeling techniques (FDTD, EME, FEM), analytical modeling, and inverse design approaches to optimize geometries and multi-parameter trade-offs. Optimization strategies will be employed to balance compactness, performance, and fabrication robustness. Experimental validation will be carried out through device fabrication, followed by comprehensive optical characterization including spectral response, propagation loss, polarization dependence, and modal purity measurements.

The PhD candidate will be responsible for device concept development, simulation and optimization workflow implementation, mask layout preparation, coordination of fabrication activities, and experimental validation. Additional tasks include formulation of design rules and scaling laws, automation of simulation pipelines, tolerance analysis under fabrication variability, and benchmarking against state-of-the-art performance metrics. The candidate will contribute to the standardization of device parameter sets for modular integration within hybrid PIC architectures and will collaborate with international partners to ensure scientific excellence and technological relevance. This PhD. work aims to strengthen cross-domain functionality, accelerate prototyping, and support the realization of next-generation integrated photonic systems.

Candidate profile

Required qualifications:

Educational background

- Master's degree (Ing./MSc.) in Electrical Engineering, Optics, Photonics, or a related technical field
- Solid foundation in electromagnetic theory, wave propagation, and integrated optics
- Familiarity with measurement methods and laboratory procedures is an advantage

Technical expertise

- Understanding of photonic integrated circuits, including material platforms and hybrid integration
- Experience with numerical simulation tools (e.g., FDTD, EME, FEM, Lumerical, or similar)
- Familiarity with optical characterization techniques is an advantage
- Programming skills (e.g., Python, MATLAB) for simulation, automation, mask layouts, and data analysis

Research and personal attributes

- Strong analytical thinking and problem-solving abilities
- Ability to independently design experiments and interpret simulation/measurement results
- Working independently and collaboratively within an international research team
- Strong communication skills, readiness to publish in journals and present at international conferences
- Proficiency in English (written and spoken)

The position is particularly suitable for candidates interested in bridging fundamental photonic device physics with scalable, application-driven integrated photonic system design.

The PhD. topic is supported by the project MULTIBAND PHOTONIC INTEGRATED LIBRARY FOR QUANTUM-OPTICAL SYSTEMS, 09I03-03-V04-00410 funded through Slovakia's National Recovery and Resilience Plan: Fellowships for excellent researchers R2-R4.

The PhD. topic is open only for internal form of study realized in Slovak or English language.