UNIVERSITY OF ŽILINA
Faculty of Electrical Engineering and Information Technology

Topic of dissertation thesis

Academic year *2026/2027*

Title	Wide bandgap integrated photonic architectures for visible and quantum technologies
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	Ing. Ján Litvík, PhD.; Mgr. Anastasiia Doroshensko, PhD. Department of multimedia and information-communication technology
Study form	Internal
Study duration	3 years (internal form)
Study language	Slovak, English
Start date	1.9.2026
Research domain	Integrated photonics; Wide bandgap platforms, Visible range; Device design; Simulations and optimization
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Dissertation topic abstract

This PhD thesis addresses the development of integrated photonic components based on wide bandgap material platforms such as silicon carbide, silicon nitride, and gallium oxide, targeting operation in the ultra-short wavelength regime. While most established photonic technologies are optimized for near-infrared telecommunications bands, emerging applications in biophotonics, quantum technologies, visible-light sensing, and free-space optical systems require robust, high-performance devices at significantly shorter wavelengths. Operation in this spectral domain introduces critical challenges, including enhanced scattering losses, strong material dispersion, stringent fabrication tolerances, and limited compatibility with mature manufacturing processes. The research focuses on the engineering of fundamental on-chip optical building blocks for light guiding, routing, and manipulation, enabling scalable and application-driven visible integrated photonics.

Extended information, research responsibilities and tasks of PhD. candidate

The proposed PhD. research focuses on the development of integrated photonic architectures based on wide bandgap material platforms such as silicon carbide (SiC), silicon nitride (Si_3N_4), and gallium oxide (Ga_2O_3), targeting operation in the visible and ultra-short wavelength regime. While conventional integrated photonics has been largely optimized for near-infrared telecommunications bands, emerging application domains, including quantum information processing, color-center-based quantum emitters, biophotonics, lab-on-chip diagnostics, visible-light sensing, spectroscopy, and free-space optical communication, require compact, robust, and scalable photonic components operating at significantly shorter wavelengths.

However, visible integrated photonics introduces a distinct set of technological challenges. Propagation losses increase substantially due to enhanced surface and sidewall roughness scattering, which scales strongly with decreasing wavelength. Material and waveguide dispersion effects become more pronounced, complicating broadband and phase-matched device operation. Furthermore, device dimensions shrink proportionally with wavelength, leading to heightened sensitivity to fabrication imperfections and process variability. The limited

availability of mature process design kits and standardized foundry flows for wide bandgap platforms further restricts rapid prototyping and large-scale integration.
Addressing these challenges requires new design methodologies, dispersion engineering strategies, tolerance-aware architectures, and hybrid integration approaches compatible with available manufacturing. The PhD. research aims to bridge this gap and establish a technological foundation for high-performance visible and quantum integrated photonic systems.

The PhD. research will concentrate on the systematic development and engineering of fundamental photonic building blocks tailored for short-wavelength operation. These include ultra-low-loss waveguides, compact bends, broadband splitters, high-Q resonators, polarization-managing structures, and high-efficiency fiber-chip coupling interfaces. The work will address wavelength-dependent scaling effects, surface-scattering mitigation strategies, and precise mode confinement control. Particular emphasis will be placed on dispersion engineering for phase-sensitive applications, tolerance-aware and variability-resilient design methodologies, and hybrid integration approaches. All developments will be aligned with scalable fabrication processes to ensure compatibility with wafer-level manufacturing and future photonic foundry ecosystems.

The candidate will be responsible for:

- Developing device concepts and multi-parameter optimization strategies
- Performing electromagnetic simulations (FDTD, FEM, EME) and analytical modeling
- Designing fabrication-ready layouts and coordinating process runs
- Conducting experimental characterization and testing
- Investigating scattering mechanisms and fabrication-induced variability
- Benchmarking performance against state-of-the-art visible photonic platforms

Candidate profile

Required qualifications:

Educational background

- Master's degree (Ing./MSc.) in Photonics, Electrical Engineering, or a closely related technical field
- Foundation in electromagnetics, wave optics, and integrated photonic circuits
- Knowledge in material and waveguide platforms for integrated photonics

Technical expertise

- Familiarity with integrated photonic device design and basic building blocks
- Experience with electromagnetic simulation tools (e.g., FDTD, FEM, EME, Lumerical, COMSOL)
- Basic understanding of nanofabrication processes and experiences with optical testing 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 work independently and within interdisciplinary research teams.
- High level of motivation for visible and quantum photonics research
- Willingness to combine theoretical modeling, numerical simulation, and experimental validation.
- Publishing experiences in high-impact journals and present at international conferences
- Proficiency in English (written and spoken)

This PhD topic is particularly suited for motivated candidates interested in combining advanced photonic device engineering, materials innovation, and development of optical building blocks in emerging short-wavelength integrated platforms.

The PhD. topic is supported by the project MULTI-PURPOSE PHOTONIC INTEGRATION PLATFORM FOR DIGITAL NETWORKING BACKBONES ENABLED BY FIBER-OPTICS AND CHIP-LEVEL INTERCONNECTS, 09I05-03-V02-00062 funded through Slovakia's National Recovery and Resilience Plan: Support of research projects aimed to digitalise the economy in TRL 1-3 (Digitalisation TRL 1-3).

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