Topic of dissertation thesis

Academic year *2026/2027*

Title	Intelligent photonic device design using hybrid deep learning architectures		
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; Deep learning, Device design; Neural networks		
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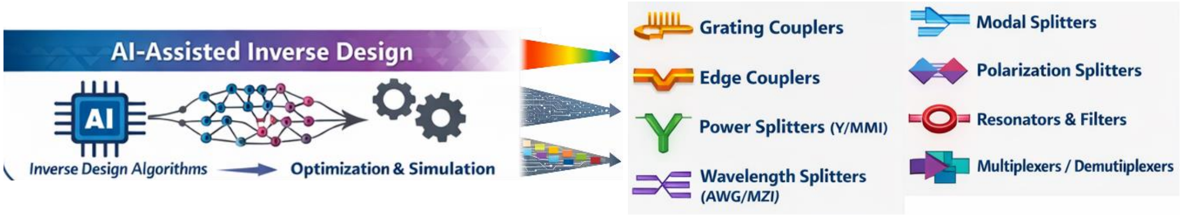
Dissertation topic abstract

This PhD. thesis focuses on the hybrid deep learning frameworks combining neural networks with evolutionary and physics-informed optimization techniques for advanced photonic device design. The research addresses limitations of conventional parametric design approaches in silicon-compatible photonic platforms, particularly for multi-objective optimization of broadband, low-loss, and fabrication-tolerant components. By integrating data-driven surrogate models with evolutionary search strategies, the work aims to enable efficient inverse design of complex photonic structures. The expected outcome is an intelligent, automated design pipeline accelerating the development of scalable, high-performance photonic integrated devices for a diverse range of applications.

Extended information, research responsibilities and tasks of PhD. candidate

The rapid advancement of photonic integrated circuits (PICs) for high-speed optical communications, advanced sensing, and quantum technologies has led to increasing device complexity and multi-parameter optimization challenges. Traditional photonic design methodologies rely heavily on parameter sweeps, intuition-driven geometrical tuning, and computationally intensive electromagnetic simulations. Such approaches become inefficient when addressing multi-objective problems involving broadband operation, low insertion loss, polarization diversity, modal control, and fabrication tolerance, among others. The growing design space dimensionality demands intelligent, automated, and scalable optimization frameworks.

This PhD research aims to leverage hybrid deep learning architectures that integrate neural networks with metaheuristic optimization techniques for inverse photonic device design. Metaheuristic methods, including genetic algorithms, differential evolution, particle swarm optimization, and other evolutionary strategies, offer robust global search capabilities in high-dimensional design spaces. Neural networks, including deep feedforward networks, convolutional neural networks (CNNs), and physics-informed neural networks (PINNs), can provide fast surrogate modeling and nonlinear mapping between structural parameters and optical responses. By combining these approaches into neuro-evolutionary or hybrid optimization frameworks, the research seeks to not only accelerate convergence, reduce simulation cost, and improve global optimality, but develop novel photonic devices with functionalities beyond conventional requirements.



The methodology involves generating large parametric datasets through electromagnetic simulations (FDTD, EME, FEM) to train surrogate neural models capable of predicting spectral response, insertion loss, crosstalk, and polarization behavior. Evolutionary algorithms will then operate on these surrogate models to efficiently explore the design space. Multi-objective optimization strategies will be implemented to simultaneously optimize bandwidth, compactness, fabrication tolerance, and performance robustness. The framework will be validated through high-fidelity simulations and, where possible, experimental prototyping in silicon-compatible platforms such as silicon and silicon nitride.

The PhD candidate will be responsible for developing simulation workflows, constructing and training neural network architectures, implementing metaheuristic optimization pipelines, and benchmarking performance against conventional design approaches. Tasks include dataset generation, model validation, hyperparameter optimization, algorithm integration, tolerance analysis, and potential fabrication coordination. The candidate will also disseminate results through publications and collaboration with academic and industrial partners.
The expected outcome is an intelligent, automated design ecosystem capable of transforming conventional photonic engineering into a data-driven, adaptive, and scalable process for next-generation integrated photonic systems.

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 photonics
- Solid background in mathematics, numerical methods, and optimization theory

Technical expertise

- Understanding of photonic integrated circuits and basic photonic building blocks
- Experience with electromagnetic simulation tools (e.g., FDTD, FEM, EME, Lumerical, COMSOL)
- Programming proficiency in Python/MATLAB, basic knowledge of machine learning
- 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
- Interest in inverse design and automated design workflows
- High motivation for interdisciplinary research at the interface of photonics and artificial intelligence
- Working independently and collaboratively within an international research team
- Willingness to publish in high-impact journals and present at international conferences
- Proficiency in English (written and spoken)

The position is particularly suited for candidates aiming to bridge advanced AI methodologies with next-generation silicon-compatible photonic device engineering.

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