20.04.2021

Master's theses (it can also be a student project depending on the qualifications of the candidate)

1) **Simplify the input of geometries for photonics simulations**
   Creating complex geometries while using self-made (or in-house) electromagnetic solvers, is not straightforward and requires quite a programming effort. Using a CAD software (such as Solidworks) would simplify the task. The student will develop an algorithm to convert a CAD design into a proprietary format for a 3D finite-difference time-domain (FDTD) in-house software.

2) **Scientific programming with a software engineering mindset**
   Computational physicists and engineers develop complex software for the simulation of physical phenomena, such as those required for the design of photonic devices. These codes (that we call "in-house" to distinguish them from commercial software) are usually not written following software engineering best practices. This results in a code that is hard to maintain and to teach to new researchers. The student will collaborate with an existing international team (that also include software developer experts) to improve an existing finite-difference time-domain (FDTD) code for photonics simulations. The student will learn how to apply software engineering best practices to scientific computing and develop a set of rules for all future code development in my research group. This will significantly enhance future use of the software and research collaborations with other teams.

3) **Predicting the optical effect of fabrication imperfections**
   Optical devices, such as metasurfaces, are usually simulated by considering one single nanoantenna with ideal shape. Real metasurfaces consist of an array of nanoantennas, which are all different due to fabrication imperfections. The student will learn how to use a software for nanophotonics simulations and conduct a study to predict how fabrication imperfections affect the optical response of the system.

4) **Inverse design of optical wave splitters**
   Optical systems consist of various components that are typically connected by a network of waveguides. It is very common to use wave splitters in such systems to divide/combine signals into/from different branches. For energy-efficient systems, these wave splitters are required to exhibit very low transmission, reflection, or radiation losses. This project uses inverse design techniques to seek the structure of such devices in order to achieve specified design objectives. The project employs numerical solutions of the electromagnetic wave equations and optimization methods to achieve the design objectives.

5) **Design optimization of vertical grating couplers**
   The interfacing between optical fibers and integrated photonic circuits plays an essential role in providing compact and efficient optical systems. Vertical grating couplers are commonly utilized to couple signals between integrated photonics and fibers. This project aims to optimize the structure and the material of vertical grating

couplers to achieve the design objectives. The project uses numerical solutions of Maxwell's equations and optimization methods to characterize and optimize efficient optical vertical couplers.

6) **Exploring quantum computing for photonics simulations**
   The interest on quantum computing keeps rising, and access to quantum computers is already provided by many companies (https://en.wikipedia.org/wiki/Cloud-based_quantum_computing). The student will investigate the opportunities that quantum computing offers to photonics, with a focus on the development of algorithms for photonics simulations and design.

Required qualifications for all projects/thesis:

- Very good programming skills,
- Very good knowledge of electromagnetic fields theory,
- Excellent communication in English.

To apply please send CV and transcripts to Prof. Antonio Calà Lesina (antonio.calalesina@hot.uni-hannover.de).