Institute of Applied Physics
Friedrich-Schiller-Universität Jena

Machine learning-based design of metamaterials & Metamaterial-based machine learning systems

The focus of the project will be on the implementation of neural networks (NN) to improve and simplify our physical models of metamaterials and nano-optical interaction. Specifically, the task will be to develop models and suitable neural networks for so called stacked metasurfaces. These are a subclass of metamaterials that consists of multiple layers of nano-structured surfaces. They allow to achieve complex optical behavior while being intuitive to model and to realize experimentally.

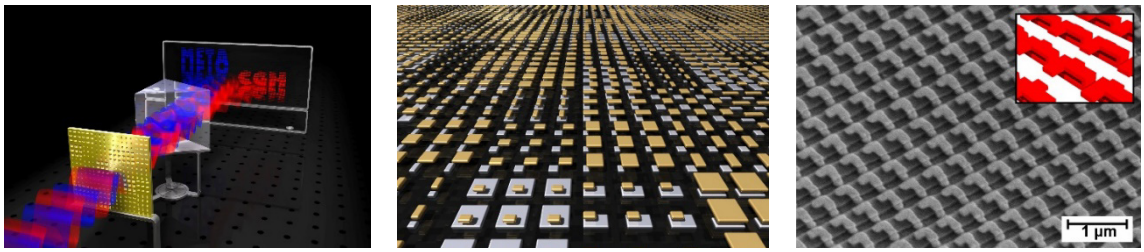
In addition, it will be studied to what extend machine learning algorithms for image recognition can be implemented directly into the optical system instead of the currently used entirely computational approaches. Due to the nature of passive parallel processing of optical information, this has the potential to dramatically speed up such algorithms and to the same extend also to reduce the necessary power consumption. If successful this would therefore open up entirely new application perspectives for real time image recognition in power limited environments.

Besides the implementation and use of machine learning algorithms the research project will be centered in the rapidly evolving field of nano-optics and metamaterials. Therefore, it will involve also the use of Maxwell's theory in order to describe the interaction between light and various arrangements of nano-particles on physical models. Due to the complexity of the underlying physics, numerical methods and simulations on high-performance computers will be employed. In combination with an intuitive analytical framework the candidate will learn to develop semi-analytic models to both understand the physical processes of metamaterials and engineer application driven solutions.

The project will be based on existing tools for the rigorous solution of Maxwell's equations as well as on Python and MatLab code. This can be used as a starting point for future work as well as to learn the basics of nano-optical modelling in combination with neural networks. The results of the work will directly impact the scientific community as the application of neural networks to stacked metasurfaces is just at the beginning.

Depending on the abilities and preferences of the candidate the following subjects would be covered

- Machine learning algorithms and neural networks for inverse system design
- Rigorous numerical simulations of nanostructured surfaces on high-performance computing systems
- Analytical modelling of complex physical systems



Typical inverse design process for metasurface construction: Left: A desired macroscopic optical functionality is the usual starting point. Center: This functionality needs to be integrated conceptually in a flat arrangement of nanostructures. Right: The functionality of specific nanogeometries has to be verified by rigorous simulations and technological implementations.

References

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