Machine Learning for the Parametric Optimization of Metasurface Photonic Devices

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Project Type:	*Master Thesis*	*Section:*	*Microengineering*
Official Start Date:	*TBD*		
Submission of Final Report:	*TBD*		
Presentations at Group Meeting:	*TBD*		

Metamaterial structures represent a promising research frontier with vast potential across various domains as technology continues to advance. The inherent flexibility in the design of metasurfaces allows for precise control over the behavior of light, making them a versatile solution for a wide range of applications. This adaptability, particularly in the design of scattering particles, is crucial, as it has the potential to significantly enhance the performance of current technologies, including absorption efficiency, wide-angle scanning, light-matter coupling, and improving the quality factor, among others. By leveraging these technological advancements, we can unlock functionalities that, until now, have only been theoretically achievable.

At the Laboratory of Advanced Electromagnetics and Photonics (LEAP), we are actively engaged in both theoretical and experimental research on scattering from metasurfaces. By leveraging the generalized sheet transition condition (GSTC), we can precisely characterize the properties of metasurfaces based on their geometries and material compositions. Given the extensive range of possible solutions—totaling 2^{21} —it is impractical to manually explore all configurations. To streamline this process and efficiently identify the optimal parameters for achieving desired optical functionalities, we would like to develop a machine-learning model. This will significantly expedite the discovery and optimization of metasurface designs, enabling more rapid advancements in the field.

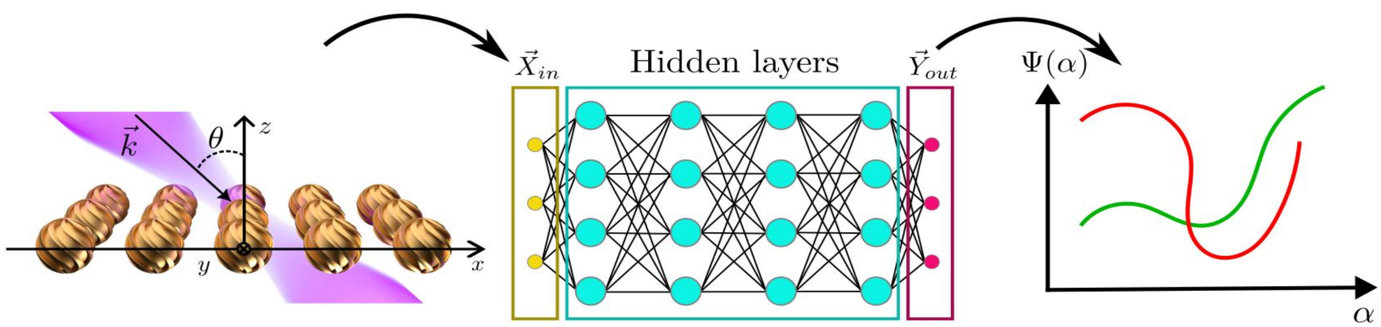

Figure 1. *Metasurface excited with an incident beam at an angle theta.*

First, the student will develop a physics-informed machine learning model to find out the best parameters to achieve desired optical responses such as the generation of vortex light, asymmetric angular scattering or pseudochiral effects. Secondly, the student will investigate inverse design methods by interfacing programming language tools such as Python, Matlab or other programming language with COMSOL to design appropriate scattering particle and achieve better results (e.g., higher efficiency).

Overall, the student will:

- Understand the physics behind the metasurfaces by applying the GSTC framework
- Search for a suitable optimization algorithm to be implemented for a specific case of the metasurfaces parameters
- Simulate the optimized parameter of the given metasurface parameters with COMSOL
- Implement the same algorithm for a set of metasurfaces of size N
- Utilize the inverse design (if time allows)

These studies will rely on quantitative and qualitative studies of the AI tool for an applied system.

Through this project, the student will gain a vast hands-on experience in AI application, theory of optical metasurfaces, electromagnetic simulation of complex structure with well-known software (COMSOL, CST). The student will also have the chance to write an article and create a git-hub repository that can benefit high impact citations.