Open student projects (last update May 2025)

Master theses, Bachelor theses, and Orientierungspraktika

Research Group Photon Management (PD Dr. Alexander Sprafke)
Interdisciplinary Center of Materials Science IZM and
Institute of Physics, FG Microstructure-based Materials Design μMD

This document describes current research projects in our group suitable for your Bachelor and Master theses as well as short-term internships (Orientierungspraktikum). We aim to keep this overview up to date but please don't hesitate to contact us directly for the most current project opportunities.

The project descriptions are general introductions to the topics and we would be happy to go into more detail upon your request. Some topics are labelled as Bachelor or Master level, however, project scopes can usually be adapted to match your academic stage. For example, a Master's topic can often be adjusted for a Bachelor's thesis. We encourage internships. An *Orientierungspraktikum* is a great way to get to know our team and research activities and vice versa.

Our group investigates the optics of nanostructured materials, aiming to realize novel optical metamaterials. A current focus lies on disordered yet highly correlated structures (ordered dIsOrDeR), such as hyperuniform-disordered materials, which exhibit an exciting mix of physical properties combining those of highly ordered with those of random structures. We also explore other physical aspects of these exotic materials, e.g. mechanical properties. We are an experimental group, however many of our works tackle theoretical/numerical challenges as well.

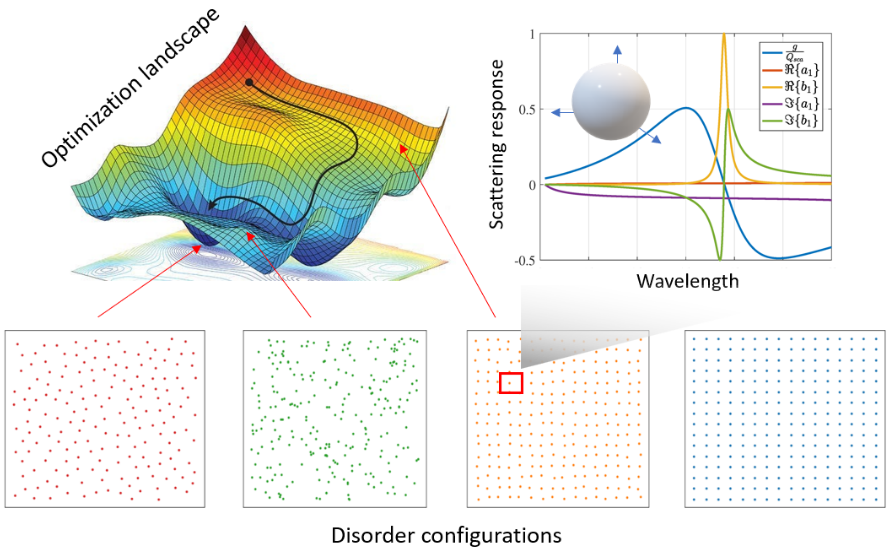

Figure 1: Inverse design of disordered media for tailored light scattering

1 Bachelor thesis: Inverse design of disordered media for tailored light scattering

Research objective

The thesis involves computational studies of disordered media. The overall system consists of identical particles spatially arranged in a disordered manner. An existing in-house code — currently limited to spatial optimization — shall be extended by enabling simultaneous optimization of the particle's physical properties for a defined optical objective, such as light-localization or anti-reflection. For simplicity, the approach here would use spheres as the scattering particles since light scattering from a single isolated sphere is analytically described by Mie Theory.

Helpful qualifications

Basic knowledge of Electromagnetic Theory and python programming.

Contact

For further queries, please contact Dr. Prerak Dhawan (prerak.dhawan@physik.uni-halle.de) or PD Dr. Alexander Sprafke (alexander.sprafke@physik.uni-halle.de).

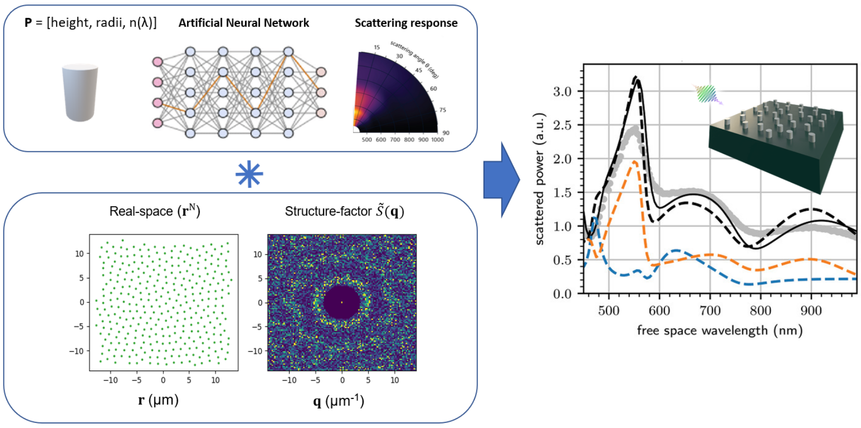

Figure 2: Artificial Neural Networks for predicting light scattering from disordered media

2 Master thesis: Artificial Neural Networks for predicting light scattering from disordered media

Background

Computational analysis of light scattering in disordered media (here: disordered arrays of identical particles) has long remained a challenging task due to the large degree of freedom in the spatial arrangement of particles. Researchers have often used approximate solutions for this problem, namely the Born's first approximation. When the spatial correlations among the particles are not intuitively known, tailoring light scattering for a certain objective, like focusing of light or suppression of reflection, can be cumbersome since typical approaches involve either tuning the individual particle properties or tuning their spatial arrangement but rarely a combination of both simultaneously. Simultaneous optimization of both is typically done for periodic arrangements but rarely for a disordered arrangement.

The thesis involves training an artificial neural network (ANN) to predict the optical response of individual scatterers with varying parameters. After validating the ANN against known Mie solutions, it will be applied to optimize complex disordered arrangements for targeted scattering properties.

Helpful qualifications

Knowledge of Electromagnetic Theory, Python programming skills for data analysis and Neural Network architectures.

Contact

Dr. Prerak Dhawan (prerak.dhawan@physik.uni-halle.de) or PD Dr. Alexander Sprafke (alexander.sprafke@physik.uni-halle.de).

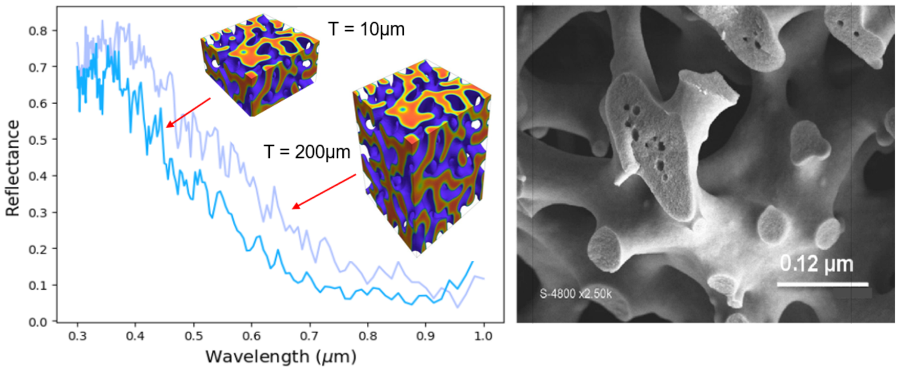

Figure 3: Light transport properties of Controlled Porous Glasses

3 Bachelor/Master thesis: Light transport properties of Controlled Porous Glasses

Background

Controlled Porous glasses (CPGs) are glasses with interconnected pore structures and their fabrication offers precise control of the mean-pore width, porosity and other quantities. This is of particular interest for mechanical and biological studies involving tensile strength, diffusion of liquids and drug delivery. However, the optical properties of CPGs are much less explored, particularly on micrometer-scale thicknesses. At this length-scale, optical effects become more pronounced due to the CPGs unique morphology. This thesis will focus on experimentally studying light transport in CPGs to shed light on its optical properties.

This thesis focuses on experimentally characterizing light transport in thin CPG membranes. Samples will be prepared via polishing or FIB-sectioning and analyzed using SEM and optical spectroscopy.

Helpful qualifications

Basic knowledge of Electromagnetic Theory, python programming, and interest in experimental lab work.

Contact

For further queries, please contact M.Sc. Davy Tesch (davy.tesch@physik.uni-halle.de) or PD. Dr. Alexander Sprafke (alexander.sprafke@physik.uni-halle.de).

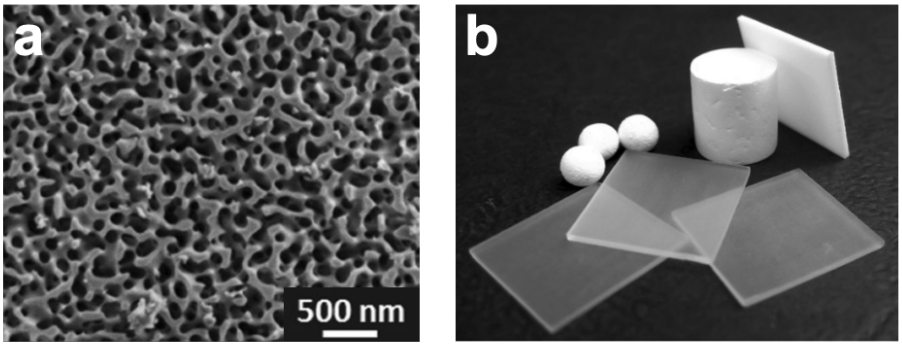

Figure 4: Fabrication of micro- and nanostructures made of Controlled Porous Glasses: (a) Microstructure of porous glass granules with pore diameter 150 nm. (b) Examples of geometric forms of porous glass monoliths (cylinder height: 8 mm)

4 Master thesis: Micro-/Nanostructuring Controlled Porous Glasses

Background

Controlled Porous glasses (CPGs) are widely in pharmaceutical, chemical, and biological applications. Usage examples include filtering, transdermal drug-delivery systems, chromatographic separation, and many more. This is attributed to its morphological features that seem disordered but yet can be tuned in a large window of parameters.

Despite these applications, the optical potential of CPGs has been scarcely explored. Their high surface area and tunable disorder make them promising candidates for optical sensing. Their high adsorption capacity and ability to act as carriers for liquids allow for tuning of their optical response: adsorbed molecules modify the effective refractive index of the porous matrix, thereby altering its overall scattering characteristics. By structuring them on the micro- or nanoscale, in this project interaction with light shall be further engineered, enabling selective detection of analytes or enhancement of weak optical signals such as Raman scattering.

Helpful qualifications

Basic knowledge of Electromagnetic Theory, python programming, and interest in experimental lab work.

Contact

For further queries, please contact M.Sc. Davy Tesch (davy.tesch@physik.uni-halle.de) or PD. Dr. Alexander Sprafke (alexander.sprafke@physik.uni-halle.de).

5 Orientierungspraktikum: Simulated Annealing for 3D Microstructures

This internship focuses on generating porous microstructures via simulated annealing based on defined statistical properties. The code will be implemented in Python and benchmarked against reference structures generated from differential equation models. Candidates with experience in Python Programming, Optimization methods and mathematical modelling background are encouraged to apply.

6 Other projects

We are never short of research ideas and would be happy to discuss with you further possible topics for your Bachelor/Master thesis or Orientierungspraktikum. Whether you are interested in pursuing an experimental for theoretical/numerical topic, feel free to contact us!