Thesis subject

Name of the laboratory: Institut Fresnel

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Subject's title: Inverse design algorithms for deriving new functional electromagnetic devices

Subject description:

There is a growing need of finding electromagnetic materials with specified functionalities. The idea is not only to derive materials which will correctly fulfill the predefined objectives but to provide solutions which will exceed the engineers expectations, e.g., more efficient at converting sunlight to electricity in photovoltaic cells, enhanced photonic circuits with reduced losses [1], refined anti-reflection coatings [2], antennas with improved quality factors [3] …

In order to discover non-intuitive solutions, one way is to recast these problems as an inverse electromagnetic design problem. The optimal shapes of the electromagnetic devices, such as the antennas, surface textures, gratings, anti-reflection coatings structures, will correspond to the outputs of the considered optimization problem.

Because of the high computational cost associated to Maxwell's equations, these optimization methods are generally applied to relatively simple geometries, with parametric descriptive features. Indeed, heuristic methods such as genetic optimization or particle swarm optimization repeatedly modify a population of individual solutions in order to find a satisfactory one. When non-parametric or freeform shapes are sought, shape optimization approaches seem to be more appropriate [4]. It appears that the underlying algorithms are similar to the ones developed for solving inverse problems [5], which arise in imaging and non-destructive applications.

In the same time, we are developing efficient electromagnetic solvers based on domain decomposition methods and FETI techniques which can be tuned to the electromagnetic scattering of periodic structures of finite length.

The goal of this thesis is thus to take advantage of the various inversion algorithms developed at Institut Fresnel and tightly couple them to dedicated direct solvers [6][7] in order to derive new multifunctional elements or surfaces for microwave and optical applications [8] [9].

Keywords — Optimization techniques – Shape optimization – Domain decomposition methods – FETI methods - Photonics - Electromagnetism
Pre-requisites — The applicant must be highly motivated student, with a Master degree (acquired in applied mathematics, numerical analysis, electrical or telecommunication engineering, optics and photonics, for example). He must have good skills in applied mathematics, computer science and possibly signal processing. Extra knowledge in electromagnetics and/or photonics will be appreciated. The applicant should also be willing to carry out strong numerical developments.

Bibliography:

[1] Inverse design of anti-reflection coatings using the nonlinear approximate inverse, M. Alakel Abazid et al, Inverse Problems in Science and Engineering 24:917, 2016
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[4] Topology Optimization: Theory, Methods and Applications, M. P. Bendsøe, O. Sigmund , Springer, 2003
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[8] Small Dielectric Spheres with High Refractive Index as New Multifunctional Elements for Optical Devices, M Tribelsky et al Scientific Reports 5:12288, 2015
[9] Electromagnetic polarization-controlled perfect switching effect with high-refractive-index dimers and the beam-splitter configuration, A. Barreda et al, Nature Comm , 2017