Optical characterisation of nanostructures using a discretised forward model - DTU Orbit (09/11/2017)

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Optical diffraction microscopy (ODM) is a non-destructive and relatively inexpensive means of characterisation of nanostructures. It is an essential tool in the design, production and quality control of functional nanomaterials. In ODM, the target is reconstructed from the measured optical power in the reflected far field. This inverse scattering problem is typically highly ill-posed due to the incompleteness of the data and the low signal-to-noise ratio. In a realistic setting, the formulation of the forward scattering model is usually complicated by the presence of supporting structures (e.g., a substrate or a grid supporting a nanoparticle), since the electromagnetic interaction between the nanostructure and the supporting structure must be taken into account. Also, the roughness and the contamination of the supporting structure can increase the dimensionality and the ill-posedness of the inverse problem. Finally, the size of the measured nanostructure is typically comparable to the wavelength of the illuminating light, so the scattering needs to be described using the full Maxwellian electromagnetic model, rather than (numerically inexpensive) asymptotic formulations.

We here describe an efficient, accurate and robust forward scattering model [1,2] based on discrete sources and tailor-made for the reconstruction of 2D nanoparticles on substrates from ODM data. We adopt an analysis-based modelling paradigm, and attempt to incorporate as much available a priori information as possible directly in the forward model. We replace the classical radiation integrals by finite linear combinations of stratified Green's functions for the Helmholtz operator in the plane, and thus achieve a sparse formulation and an implicit description of the particle-substrate interaction. The forward model can be extended to include the roughness and contamination of the substrate without sacricing the speed of computation [3]. We validate the model and show its feasibility in a decomposition-type inverse scheme with synthetic measurement data ([1], figure 1), as well as in the inversion of experimental scatterometric data ([4], figure 2). Finally, we use a related forward model in the inversion of synthetic measurement data to estimate aperiodic defects in a nanograting ([5], figure 3).

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Inverse problems are problems that consist of finding an unknown property of an object or medium through the observation of a response from this object or medium to a probing signal. Thus, the theory of inverse problems yields a theoretical basis for remote sensing and non-destructive evaluation.Â This book presents the theory of inverse spectral and scattering problems and of many other inverse problems for differential equations in an essentially self-contained way.Â These equations are finding an increasing number of applications in physical problems involving random phenomena, and others that are only now beginning to emerge, as is happening with the current use of stochastic models in the financial world. This book provides a comprehensive introduction to the techniques, tools and methods for inverse problems and data assimilation, and is written at the interface between mathematics and applications for students, researchers and developers in mathematics, physics, engineering, acoustics, electromagnetics, meteorology, biology, environmental and other applied sciences. Basic analytic questions and tools are introduced, as well as a wide variety of concepts, methods and approaches to formulate and solve inverse problems. OCTAVE /MATLAB codes are included, which serve as a first step towards simul Nonlinear inverse problems appear in many applications, and typically they lead to mathematical models that are ill-posed, i.e., they are unstable under data perturbations. Those problems require a regularization, i.e., a special numerical treatment.Â [Show full abstract] inverse problem can be reduced to the inversion of a sparse linear algebraic system.Â We demonstrate our method in simulation by calculating the refractive index distribution of a hypothetical 2-D gradient-index element from computer-generated external beam deflection data, where RMS index errors below 1% of the index range (nmax âˆ' nmin) are achieved. Read more. Article. A numerical solution of the linear multidimensional unsteady inverse heat conduction problem with th