Simulating scattering from finite structures: an extended Fourier modal method

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The Fourier modal method (FMM) is widely used in the diffractive optics community as an efficient tool for simulating scattering from infinitely periodic gratings. In reality the gratings are finite in size, and in applications such as lithography, it is desirable to make them as small as possible. At a certain point the assumption on infinite periodicity loses its validity. This thesis addresses the issues of extending the FMM to finite structures and consequently improving the stability and efficiency of the newly developed method.

The aperiodic Fourier modal method in contrast-field formulation (aFMM-CFF) is developed by placing perfectly matched layers at the lateral sides of the computational domain and reformulating the governing equations in terms of a contrast field which does not contain the incoming field. Due to the reformulation, the homogeneous system of second-order ordinary differential equations from the original FMM becomes non-homogeneous. Its solution is derived analytically and used in the established FMM framework. The technique is first demonstrated on a simple problem of planar scattering of TE-polarized light by a single rectangular line. Later the method is generalized to arbitrary shapes of scatterers and conical incidence.

The contrast-field formulation of the equations modifies the structure of the resulting linear systems and makes the direct application of available stable recursion algorithms impossible. We adapt the well-known S-matrix algorithm for use with the aFMM-CFF. To this end stable recursive relations are derived for the new type of linear systems. The stability of the algorithm is confirmed by numerical results.

The efficiency of the aFMM-CFF is improved by exchanging the discretization directions. Classically, spectral discretization is used in the finite periodic direction and spatial discretization in the normal direction. In the light of the fact that the structures of interest have a large width-to-height ratio and that the two discretization techniques have different computational complexities, we propose swapping the discretization directions. Among other, this step requires a projection of the background field on the new basis introduced by the alternative discretization. As shown by numerical experiments, depending on the problem, a considerable reduction of the computational costs may be obtained.