Exact boundary conditions for scattering problems with periodic exterior domains

Therese Pollok and Frank Schmidt

Zuse Institute Berlin, Takustraße 7, 14195 Berlin, Germany
pollok@zib.de, frank.schmidt@zib.de

Periodic structures such as metamaterials or photonic crystals have many applications in modern optical devices due to their optical properties (e.g. the occurrence of band gaps or negative refractive indices). Particularly defects within the periodicity of a bandgap material are of special interest since they can be used to guide or trap light efficiently, as it is desired for example in optical telecommunication or laser technologies. For the optimization of such structures, efficient simulations are required.

In real world applications the size of photonic crystals is often very large compared to the size of their inner structures. Therefore, they are typically assumed to extend to infinity. By splitting the unbounded domain into a bounded interior domain $\Omega_{\text{int}}$ and an exterior domain $\Omega_{\text{ext}}$ and applying proper boundary conditions at the interface, the computational domain can be restricted to $\Omega_{\text{int}}$.

The boundary conditions have to take into account the correct radiation condition at infinity. Compared to transparent boundary conditions for homogeneous or simply structured exterior domains, the formulation of exact boundary conditions at the interface to a periodic exterior domain is much more involved since it has to take backscattering into account. For an efficient modeling of light propagation in periodic media with defects the accurate representation of these boundary conditions is essential. Current approaches typically deal with specific geometries e.g. line defects or local defects in two space dimensions and can not be generalized to higher space dimensions or more complex geometries in a simple manner. We will present a new concept to construct boundary conditions for periodic exterior domains, that is dimension independent and can be applied to problems with local defects as well as defects with a more complex structure.