Boundary Integral Spectral Element Method with Periodic Layered Medium Green's Function

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Efficient and accurate simulation of the periodic layered structures has been a critical topic in the numerical analyses in the design of nano scale optoelectronic structures. As one of the most promising approaches, finite element boundary integral (FE-BI) method has drawn intensive attentions. However, several challenges exist for building a robust and accurate FE-BI solver. First, most existing FE-BI solver focuses on homogeneous background. When analyzing the inhomogeneous scatterer embedded in stratified structure, the computational domain needs to include the layered background structure, which usually imposes heavy burden on the computation resources. In addition, when the boundary integral domain is placed adjacent to the layered medium interface, several components of the dyadic periodic Green's function converges slowly. The same issues presents when analyzing thin-layer background.

In this work, we propose a numerical solver combing the boundary integral spectral element method (BI-SEM) with the dyadic periodic layered medium Green's function. As the first step, the dyadic periodic layered medium Green's function is formulated under wave function formulation. The surface integral equations (SIE's) are then implemented as the radiation boundary condition to truncate the top and bottom computation domain. Within this context, singularity extraction is applied to further accelerate the convergence rate of critical periodic summations. After describing the interior computation domain with the vector wave equations, and treating the lateral boundaries with Bloch periodic boundary conditions, the whole computation domains are discretized with mixed-order Gauss- Lobatto-Legendre basis functions.

Various numerical results are shown to validate the proposed method as an efficient solution for the numerical analyses of periodic structures embedded in layered medium. The performance for simulating the conventionally challenging thin-layered structures are also provided and discussed.