Self-consistent numerical solver for wave optics simulation based on hybrid boundary-integral spectral element method

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Development of advanced numerical solvers for efficient and accurate wave optics simulation, including linear and nonlinear processes, is essential for the estimation, design, and fabrication of opto-electronic devices. The boundary-integral spectral element method (BI-SEM) has demonstrated considerable promises in computational electromagnetics, yet related higher order methods have not been elegantly extended to the area of computational optics/ photonics. In this work, a self-consistent numerical solver is proposed for wave optics simulation. Starting from the BI-SEM theory, highly efficient numerical solver is developed for linear and non-linear optical simulation for both periodic and non-periodic structures. With a novel hybrid radiation boundary condition, the solver can self-consistently switch between periodic simulation and non-periodic simulation with minimum cost. In the meantime, the layered structure commonly encountered in optical designs are also carefully addressed. Combined with the matrix-friendly periodic dyadic layered medium Green's function and the block-Thomas method, both the flat stratified medium and the multi-layer structure with curvature can be efficiently analyzed. Typical testing applications have validated the proposed solver's great potential in both performance estimation, such as defect analyses in extremely ultraviolet lithography, and opto-electronic structure design, such as the third-harmonic engineering of graphene. As an on-going investigation, singularity subtraction for the thin layered structure and the domain decomposition method are being integrated with current solver for further performance enhancement.

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