A Fast Simulation Method for 3D Photonic Crystals

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The novel properties of photonic crystals, the artificial photonic structures whose refractive indices vary periodically on the scale of the wavelength of light, have attracted active research in the design of such new materials. For infinite periodic structures, under certain conditions a photonic crystal possesses a photonic bandgap (PBG) in which light propagation in any direction is prohibited. The design of photonic crystals with various bandgap properties calls for fast and accurate simulation of light interacting with complex dielectric structures. Ongoing efforts focus on the finite-difference time-domain (FDTD) method, pseudospectral time-domain (PSTD) method, finite-element method, and plane wave expansion method. Although such methods prove highly useful for infinite periodic structures (where only one period needs to be simulated) and for small truncated periodic structures, they are still very time consuming for large-scale truncated periodic structures where no periodicity conditions can be used to reduce the computational domain to a single period.

In this work, we propose to develop a fast simulation method for photonic crystals with the newly proposed volume adaptive integral method (VAIM). The VAIM is a fast integral equation method for electromagnetic scattering from 3D inhomogeneous objects (Zhang and Liu, *IEEE Antennas Wireless Propagat. Lett.*, vol. 1, no. 6, pp. 102–105, 2002). By projecting the unknown induced current density within an arbitrary element in the inhomogeneous object onto a fictitious uniform grid, this method accelerates the calculation of the far-zone interactions of basis and testing functions through the fast Fourier transform, thus greatly reducing the memory requirement to $O(N)$ and CPU requirement to $O(N \log N)$, where N is the number of unknowns. The numerical results have been validated by the method of moment. Application to photonic crystals will be illustrated to show the efficacy of this method.