A Boundary Element Method for the Analysis of Inhomogeneous Photonic Crystals

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A fast numerical method for determining photonic bandgaps in composite and inhomogeneous dielectric materials is developed.

It is known that for the propagation or scattering of electromagnetic waves in a medium containing M dielectric bodies arranged periodically (photonic crystal), there exist refractive indices for which such structures have bandgaps, i.e., frequencies for which no waves can propagate inside. Such crystals have many technological applications (fiber optics, cellular telephones, semiconductor industry, etc.). The main purpose of this work is precise numerical simulations on novel dispersive and refractive phenomena in photonic crystal waveguides. In detail we study the influence of specially configured crystal inhomogeneities and physical boundary conditions to tailor the performance of planar and finite 2D-photonic bandgap structures. In order to sufficiently high accuracy in the simulations our calculations are based on a rigorous scattering theory for finite size two-dimensional photonic crystals. The results will be compared with other state-of the art algorithms. In particular, we compute the transmitted wave from an incident plane wave and analyze it for different angles of incidence, and we try and find the frequencies that generate the prohibited waves. In this work we choose a method that is based on boundary integral equations. We derive single integral equations on each of the interfaces between two regions by using a hybrid method of layer potentials and Green's formula. The integral equation we need to solve is of Fredholm type and the problem can be shown to be well-posed. Our technique has many distinct advantages. First, since the approximations are made on the boundary we reduce the dimension of the problem from N to $N-1$. Second, our formulation is different than the usual formulation since for dielectrics (in electromagnetic problems), the number of unknowns is reduced by half. The only drawback is that we have, as usual for BIE, dense matrices in the resulted linear algebraic systems. But this can be remedied by using fast multipole algorithms. Details of the numerical implementation and results will be presented. We also analyze the effect of defects, that is the case when periodicity is violated.