"*Parallel computation of photonic band gaps*"

Christian Wieners Karlsruhe Institute of Technology, Germany

Abstract

We investigate photonic crystals, modeled by a spectral problem for Maxwell's equations with periodic electric permittivity. By Floquet-Bloch theory, the spectrum has a band-gap structure, and the bands are characterized by families of eigenvalue problems on a periodicity cell, depending on a parameter k varying in the Brillouin zone K. The numerical approximation of a band gap requires the accurate computation of several eigenvalues for sufficiently many parameters k.

We introduce a parallel multigrid method for Maxwell's equations discretized with suitable modified finite elements in order to handle the quasi-periodic boundary conditions (depending on the parameter k which introduces a complex shift along periodically identified boundaries). This is used as a preconditioner in the iterative eigenvalue solver LOBPC. Here, it is required to modify the LOBPC method by including a projection onto the divergence free vector fields in every iteration step. Again, this projection is realized by a parallel multigrid method. We demonstrate the efficiency of this method by several examples, where we show how it can be employed for improving the design of the photonic crystal.

Furthermore, the finite element eigenvalue approximation is compared with a Galerkin boundary element method combined with the contour integral method. Finally, we show that this approach can be combined with error controlled residual evaluations, a suitable eigenvalue homotopy, analytic embeddings, and estimates for the resolvent set in order to verify the existence of band gaps.

References:

C. Wieners, J. Xin: Boundary Element Approximation for Maxwell's Eigenvalue Problem. Mathematical Methods in the Applied Sciences 36 (2013) 2524-2539

C. Wieners: Calculation of the photonic band structure In: Photonic Crystals. Mathematical Analysis and Numerical Approximation (ed. W. Dörfler) Birkhäuser, New York (2011) 40-62

V. Huang, M. Plum, and C. Wieners: A computer-assisted proof for photonic band gaps. Z. angew. Math. Phys. (ZAMP) 60 (2009) 1035-1052