UMEÅ UNIVERSITET

Reliable *hp* finite element computations of scattering resonances in nano optics

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Akademisk avhandling

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Fakultetsopponent: Professor Jeffrey Ovall, Department of Mathematics and Statistics, Portland State University, USA.

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Abstract
Eigenfrequencies are commonly studied in wave propagation problems, as they are important in the analysis of closed cavities such as a microwave oven. For open systems, energy leaks into infinity and therefore scattering resonances are used instead of eigenfrequencies. An interesting application where resonances take an important place is in whispering gallery mode resonators.

The objective of the thesis is the reliable and accurate approximation of scattering resonances using high order finite element methods. The discussion focuses on the electromagnetic scattering resonances in metal-dielectric nano-structures using a Drude-Lorentz model for the description of the material properties. A scattering resonance pair satisfies a reduced wave equation and an outgoing wave condition. In this thesis, the outgoing wave condition is replaced by a Dirichlet-to-Neumann map, or a Perfectly Matched Layer. For electromagnetic waves and for acoustic waves, the reduced wave equation is discretized with finite elements. As a result, the scattering resonance problem is transformed into a nonlinear eigenvalue problem.

In addition to the correct approximation of the true resonances, a large number of numerical solutions that are unrelated to the physical problem are also computed in the solution process. A new method based on a volume integral equation is developed to remove these false solutions.

The main results of the thesis are a novel method for removing false solutions of the physical problem, efficient solutions of non-linear eigenvalue problems, and a new a-priori based refinement strategy for high order finite element methods. The overall material in the thesis translates into a reliable and accurate method to compute scattering resonances in physics and engineering.

Keywords
Scattering resonances, Helmholtz problems, pseudospectrum, Lippmann-Schwinger equation, finite element methods, nonlinear eigenvalue problems, spurious solutions.

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