Summary

This thesis deals with the characterization of localized states of resonant optical structures. We restrict ourself to one and two dimensional photonic crystal structures.

A photonic crystal structure is an optical structure with a periodic arrangement of refractive indices. It is widely known that such structures may have a certain frequency range where the propagation of light is forbidden. The first topic in this thesis is about the simplest case of a photonic crystal structure, namely it is the infinite one dimensional grating. We have developed a variational characterization that gives directly the band gap edges of the first band gap. The numerical implementation of the characterization is done using the Finite Element Method (FEM). To illustrate the method, we study a grating that is build from two different materials. For this specific type of grating, explicit solutions are available for linear materials, and hence it is possible to compare results. The characterization of the band gap edges can also be used for grating structures with smooth index variation, or even for nonlinear index variations.

When we consider a finite grating structure of which the periodicity is broken by a defect layer, localized defect states may exist. The feature of these localized states is that their frequency lies inside the band gap, and that the field is largely enhanced or attenuated; a complex superposition of the two states provides the full transmission mode. For application purposes it is important to be able to identify the defect frequency. We have derived a direct characterization of the defect frequency and these localized states, without having to 'scan' the whole band gap range. The characterization exploits the use of a so-called effective boundary condition; the problem of

finding the defect frequency then becomes the problem to solve a nonlinear eigenvalue problem for the defect layer only.

Different from the usual time harmonic investigation of transmittance, we also studied time limited influx, in particular when a pulse with spectral components inside the bandgap is influxed to the defect grating structure. We developed a Finite Element Time Domain (FETD) scheme to solve this, where the use of exact time domain Transparent Influx Boundary Condition (TIBC) is essential. Two different phases can be identified in the process, namely a loading and an unloading phase. We have developed a low dimensional model for the loading and the unloading phenomenon, where we assumed that it is sufficient to consider only a single mode to describe the phenomenon. Using this model we are able to quantify the build up of the field during the loading phase and the decay of the field during the unloading phase in terms of the energy content of the field inside the structure. This provides a direct relation between the quality factor and the decaying field.

The above mentioned study on the time dependent phenomenon for the defect grating structure is extended to two dimensional photonic crystal structures. For the two dimensional photonic crystal structure resonant modes may also exist. We use a two dimensional Finite Element Method as calculation tool, equipped with Transparent Influx Boundary Condition (TIBC). We study pulses as influx, with the spectral components centered around each defect frequency. The excited modes decay in time and leak their energy towards the exterior. We modeled this decay with a leaky mode, a decaying solution of the Helmholtz equation with only one (complex valued) frequency component. We characterized the leaky modes of the structure; the use of the TIBC leads to a nonlinear (non-polynomial) eigenvalue problem. The nonlinear eigenvalue problem was solved by means of a fixed point iteration scheme. Using the properties of the mode, we are able to describe the decay of the leaky modes as well as the quality factor.