Variational coupled mode theory and perturbation analysis for 1D photonic crystal structures using quasi-normal modes

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Quasi-normal modes are used to directly characterize defect resonances in composite 1D Photonic Crystal structures. Variational coupled mode theory using QNMs enables quantification of the eigenfrequency splitting in composite structures. Also, variational perturbation analysis of complex eigenfrequencies is addressed.

Summary

We analyze resonances in coupled optical defect cavities realized in finite one-dimensional Photonic Crystals. Viewing these as open systems where waves are permitted to leave the structures, one obtains eigenvalue problems for complex frequencies (eigenvalues) and Quasi-Normal-Modes (eigenfunctions), see [1] and references therein. Single defect structures (photonic crystal atoms) can be viewed as elementary building blocks for multiple-defect structures (photonic crystal molecules) with more complex functionality. The variational CMT formalism using QNMs links the resonant behavior of individual PC atoms to the properties of the PC molecules via eigenfrequency splitting [2]. A variational principle for QNMs permits to predict the eigenfield and the complex eigenvalues in PC molecules starting with a field template incorporating the relevant QNMs of the PC atoms. Further, both the field representation and the resonant spectral transmission close to these resonances are obtained from a variational formulation of the transmittance problem using a template with the most relevant QNMs [1]. Restriction of the field template in variational CMT formalism to QNMs of the unperturbed structure leads to the perturbation theory approximations for the complex eigenfrequency. The method applies to both symmetric and nonsymmetric single and multiple cavity structures with weak or strong coupling between the defects [1, 2].

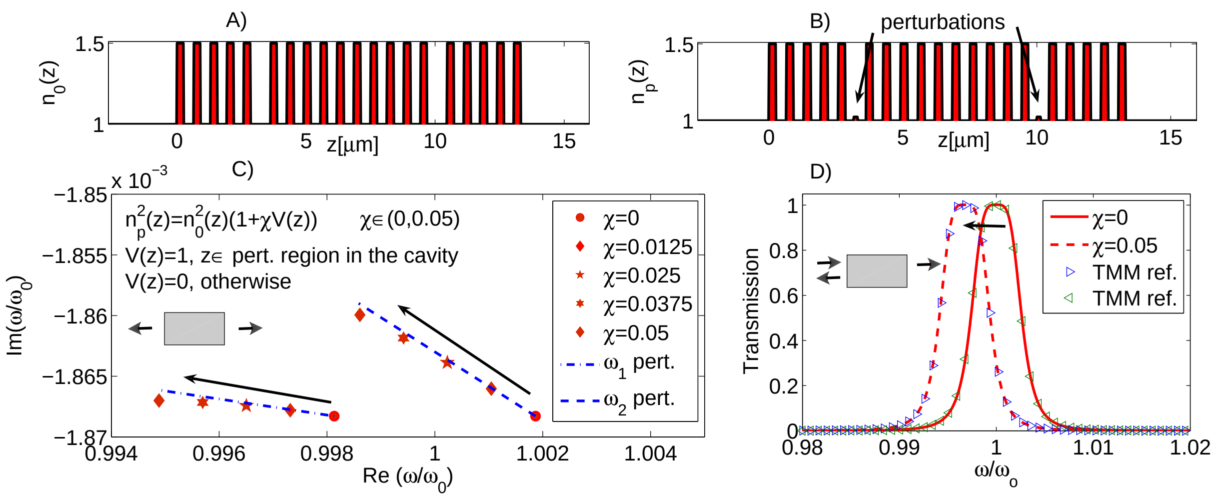

Fig. A) and B) refractive index distributions for the double cavity structure; C) complex eigenfrequencies (of defect resonances), direct computations and perturbation theory approximations; D) spectral transmittance, QNM approximation [2] based on exact QNM supermodes, and TMM reference; symmetric perturbations. The thicknesses of layers are quarter-wavelength (with half-wavelength defects) for reference frequency ω_0.

References

[1] M. Maksimovic, M. Hammer, E. van Groesen, *Optics Communications*, **281**, 1401–1411, (2008).

[2] M. Maksimovic, M. Hammer, E. van Groesen, *Proceedings of SPIE*, **6896**, 6896-05, (2008).