Dimensionality reduction for 3D vectorial optical scattering problems

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The spatial dimensionality of vectorial 3D frequency domain optical scattering problems is reduced by means of a global expansion of the field in one direction in slab modes of some reference slice(s). A variational formalism yields the equations in the other two directions. These coupled partial differential equations are solved using a Finite Element Method with modified Transparent Influx Boundary Conditions with PMLs.

Summary

By means of a global expansion over TE and TM slab modes in one direction, the dimensionality of vectorial 3D scattering problems is reduced. A Finite Element Method solves the resulting system of 2D equations; the boundaries of the calculation window are made to be transparent to outgoing light by utilizing modified Transparent Influx Boundary Conditions with PMLs. At the top and bottom of the window, PMLs are used to absorb vertically scattered radiation. We demonstrate that in case of a photonic crystal waveguide the current method with one mode in the expansion predicts the location of the bandgap and other spectral features much more precisely than a standard Effective Index Method, at more or less the same computational cost. More modes in the expansion allow radiation loss to be taken into account, and bring the results closer to a 3D FDTD reference result. Figure 1 summarizes some example results.

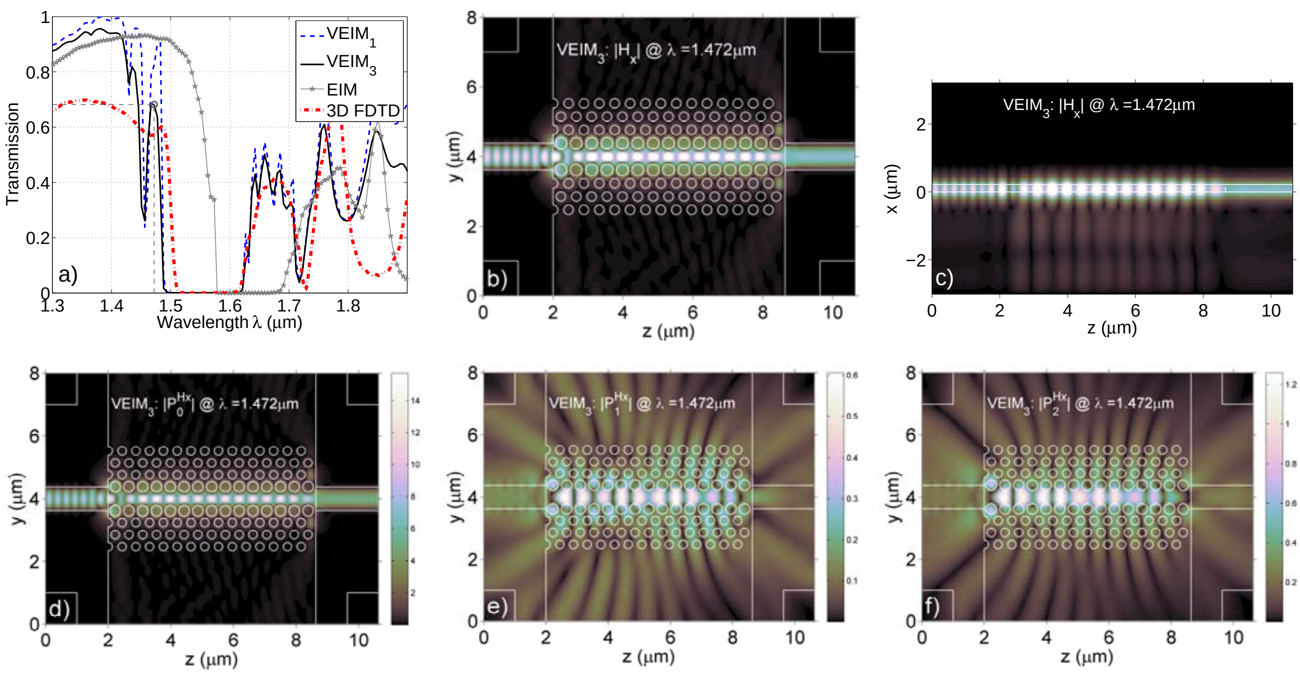

Figure 1: a) Transmission spectrum of a photonic crystal waveguide; results with 1 ($VEIM_1$) and 3 ($VEIM_3$) TE slab modes in the expansion, compared with 3D FDTD results. b)-f) are plots for $VEIM_3$ at λ=1.472μm. b) $|H_x|$ in a y-z cross-section through the middle of the waveguide (x=0.11μm). c) $|H_x|$ in an x-z cross-section along the waveguide axis at y=4μm. d)-f): coefficient-functions P_j^{Hx} of the fundamental, first and second order slab mode j=0,1,2 used in the expansion.