Variational Effective Index Method for 3D Vectorial Scattering Problems in Photonics: TE Polarization

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Abstract— Fully vectorial 3D simulations of photonic components are often almost prohibitively CPU-time and memory-intensive, so one would opt for reduced models that capture the essence of the full 3D structure, while being computationally much more efficient. Traditionally, integrated optics designers use a technique called the Effective Index Method (EIM) to reduce a simulation of a 3D structure to two spatial dimensions. However, frequently, as is the case for the photonic crystal slabs (Figure 1), the effective parameters for the 2D simulation are only rather ambiguously defined, i.e., rely more or less on guesswork. Here we have developed a mathematical formulation that allows to a priori derive these parameters when going from 3D to 2D based on a sound variational reasoning (Variational EIM, VEIM). This is achieved by approximating the total 3D vectorial electromagnetic field along one spatial dimension by a suitable 1D TE mode profile. Then, by means of a variational procedure, the field distribution in the other two dimensions is found, such that the product of these two fields represents as well as possible the true 3D vectorial solution. On the boundaries of the computational domain we use combined Transparent Influx Boundary Conditions with Perfectly Matched Layers in order to allow influx into the domain to be prescribed and radiation to freely pass through the computational window boundaries. Results for a photonic crystal slab waveguide show that this approach predicts the location of the bandgap and other spectral features much more precisely than any guesses using a 'standard' EIM. A similar procedure has also been developed for TM polarization. Currently, work is in progress to extend the method to deal with the third dimension even more accurately.

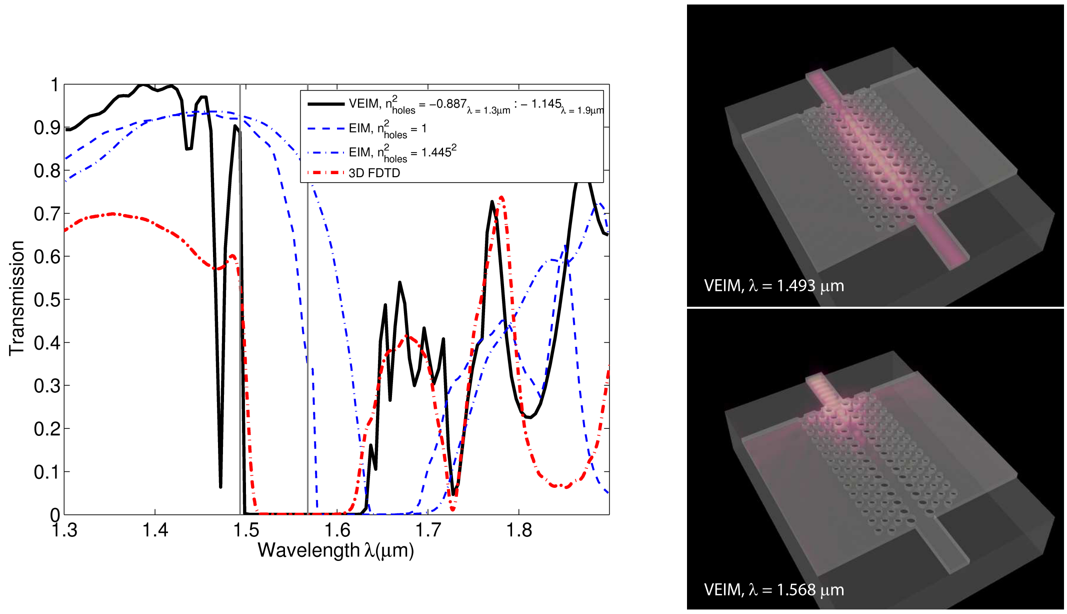

Figure 1: Left: Transmission spectrum of the photonic crystal waveguide. The VEIM predictions of the location of the stopband and the general spectral features are reasonably close to the 3D FDTD reference results, while the 'conventional' EIM data, using either the cladding (1.0) or substrate refractive indices (1.445) as effective values for the hole regions, are much further off. Right: Light propagation through the photonic crystal slab waveguide, absolute value of the principal magnetic component of the optical field; almost full transmission at a vacuum wavelength of 1.493 μm and hardly any transmission at 1.568 μm.