Variational Effective Index Mode Solver

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NanoNed-Flagship NanoPhotonics

Keywords: dielectric waveguides, mode analysis, effective index method

The effective index method (EIM) is one of the most popular among the many approaches for the modal analysis of dielectric optical waveguides [1]. While being rather intuitive and computationally very efficient, the inherent approximations limit the range of applicability of the EIM. For example, if all modes of some slab region are below cut-off, heuristics have to be applied to provide the necessary effective indices, and mode profiles are not defined. As an alternative to other approaches for improvements (e.g. [2], [3]), here we propose a method (VEIM) which overcomes these problems by means of a slightly modified ansatz for the modal field, together with the use of a Variational principle. The procedure is applicable in practice for an arbitrary, piecewise constant rectangular permittivity distribution.

The main idea is to represent the field profile as a superposition of all guided modes of the constituting slab waveguides, times some unknown continuous coefficient functions that are defined on the entire lateral axis. Restricting the functional for the semi-vectorial mode equations to the trial fields and requiring this functional to become stationary, leads to a scalar transverse resonance condition. By identifying roots of that expression one finds propagation constants and the lateral profiles.

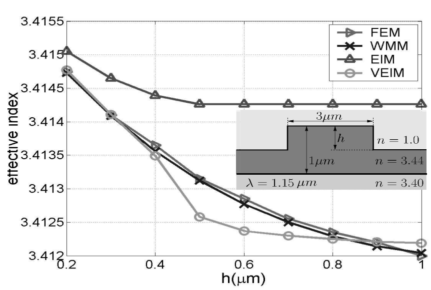

Fig. 1 *Rib waveguide: effective indices of TE-like modes versus rib depth h; FEM, WMM, EIM: reference results [4], VEIM: the present method.*

As an example, we applied this method for the analysis of the rib waveguide and 3D coupler of Figs. 1 and 2 respectively. Propagation constants of the latter structure in comparison with other rigorous methods are summarized in Table 1. Apparently the VEIM results agree better with the data from rigorous methods, than the "standard" EIM results.

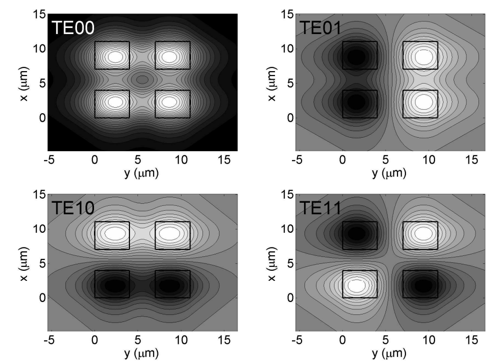

Fig. 2 *Mode profiles of a 3D coupler, 4 identical square cores with sides of 4 μm and refractive index 1.512, embedded in a background with refractive index 1.506, at a distance of 3 μm; dominant electric field component of semivectorial TE fields for a wavelength of 1.32 μm.*

	β_{00}^{TE}/κ	β_{01}^{TE}/κ	β_{10}^{TE}/κ	β_{11}^{TE}/κ
FEM	1.50758	1.50680	1.50680	1.50602
WMM	1.50790	1.50711	1.50711	1.50647
EIM	1.50804	1.50721	1.50756	1.50673
VEIM	1.50779	1.50699	1.50697	1.50618

Table. 1 *Effective indices of the modes of 3D coupler; FEM, WMM: reference results [4], EIM: effective index method, VEIM: the present method.*

In conclusion, while the VEIM approach allows to estimate propagation constants with reasonable accuracy and provides continuous, well-defined mode profiles, it largely preserves the simplicity and the computational efficiency of the "standard" EIM.

References

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