Hybrid Coupled Mode Modelling in 3-D

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Frequently, the functioning of an integrated-optical circuit can be understood in terms of the interaction of modal fields, the simulation and design of which is well established through numerical eigenproblem-solvers. It then remains to predict the interplay of these modes. We address this task by a "Hybrid" variant (HCMT) of Coupled Mode Theory. The formalism of Ref. [1] has been extended to spatially three-dimensional configurations, leading to efficient, quantitative, and interpretable models in the frequency domain.

Starting point is a physically plausible expression for the electromagnetic field in a composite circuit. Suitable modes of its constituting elements are computed numerically by means of a commercial finite-element solver [2]. Then the total field is approximated as a superposition of these vectorial profiles, with amplitudes that are functions of their — potentially different — "natural" propagation coordinates. Discretization of these into 1-D finite elements, followed by Galerkin-type projection, leads to small-size systems of linear equations. Their solutions permit to inspect the wave interaction in terms of the variations of the amplitude functions, and to assemble approximations of the overall optical fields.

This contribution outlines the theoretical background, and discusses briefly limitations and implementational details. Beyond a series of consistency checks, our first results include simulations of configurations consisting of straight channels with fairly arbitrary rectangular cross section, position, and orientation. Figure 1 shows an example.

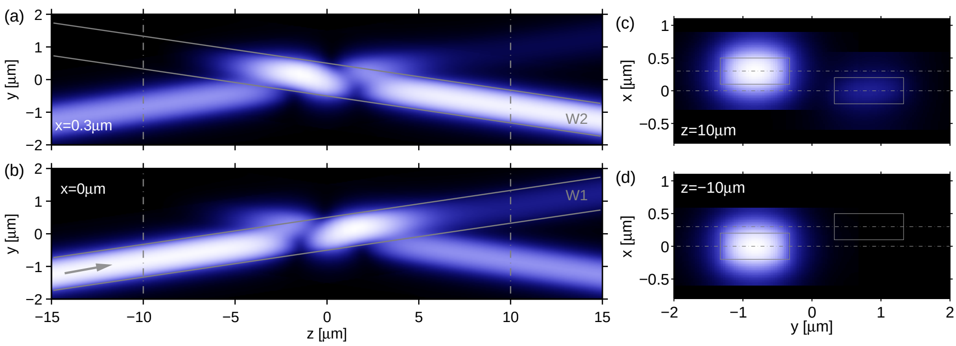

Figure 1: X-crossing of two partly intersecting straight channels. Rectangular cores (1.0 µm × 0.4 µm, refractive index $1.99 : 1.45$) cross at an angle of $9.44°$. The plots show the absolute value $|\boldsymbol{H}|$ of the optical magnetic field, on the horizontal y-z-planes at the center levels $x = 0.3$ µm, $x = 0$ of the upper (a, W2) and lower waveguide (b, W1), and on the vertical planes at $z = 10$ µm (c, output) and at $z = -10$ µm (d, input), for TE-like excitation (arrow) at a wavelength of 1.55 µm. The HCMT simulation predicts output powers of 1% (W1, TE), 3% (W1, TM), 93% (W2, TE), and 3% (W2, TM) carried by the vectorial, TE- or TM-dominant modes.

References

[1] M. Hammer. Hybrid analytical / numerical coupled-mode modeling of guided wave devices. *Journal of Lightwave Technology*, 25(9):2287–2298, 2007.
[2] JCMwave GmbH, Berlin, Germany; http://www.jcmwave.com .