Pseudospectral Beam Propagation Method and Finite Element Method: A Hybrid Technique in Computational Photonics

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The application of pseudospectral method for strongly guiding and longitudinally varying waveguides has shown that this method is superior to the classical beam propagation method (also known as the split step beam propagation method) and a widely used variation based on the finite element method (FE-BPM). In the light wave analysis of more sophisticated optical devices such as beam splitters and couplers, earlier beam propagation methods have been combined with conventional methods such as finite element method to solve for sharp inhomogeneities encountered in these structures.

In this work, we develop a hybrid technique comprised of the pseudospectral beam propagation method and finite element method to study the propagation of light in optical waveguiding structures with sharp inhomogeneities. Such a mixed-scale problem is divided into two parts: (a) the slowly varying waveguides are treated by the pseudospectral beam propagation method (Deshmukh and Liu, IEEE Photon. Technol. Lett., Jan. 2003); (b) the strong inhomogeneities (such as a coupler) are treated by the finite-element method. As an illustration of the utility of this technique we apply the following technique to an optical beam coupler. Essentially this structure consists of a 4-port junction connected to optical waveguides at each of the ports. The interface of the junction with waveguides at each of the ports represents the sharp inhomogeneity in the complete optical waveguiding setup. The exponentially accurate pseudospectral beam propagation method is applied to each of the waveguides attached to the junction. The junction is analyzed using the finite element method. The propagation solutions obtained from the pseudospectral beam propagation method and finite element method are reconciled by applying the boundary conditions at the each of the interfaces of the 4-port optical beam coupler. This hybrid method is superior to earlier methods employing combinations of beam propagation methods and conventional finite element methods.