Helmholtz solver with transparent influx boundary conditions and nonuniform exterior

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Boundary conditions for a 2D finite element Helmholtz solver are derived, which allow scattered light to leave the calculation domain in the presence of outgoing waveguides. Influx of light, through a waveguide or otherwise, can be prescribed at any boundary.

In the simulation of integrated optical structures, the boundaries of the calculation window are an important issue. They should act as if they were not there; in principle the boundary conditions should incorporate the solution of the equations in the exterior. Thus, scattered light from structures in the interior should leave the domain unobstructed, and it must be possible to prescribe the influx of light from the exterior to the interior. Such Transparent Influx boundary conditions (TIBC's) can be described in terms of a so-called Dirichlet-to-Neumann (DtN) operator, which relates the field on the boundary to its normal derivative, such that the solution represents only outfluxing fields. Similarly, influxed fields may be prescribed. In [1], approximations of the DtN operator are applied on a computational domain with a smooth boundary; these operators are local. Contrarily, [2] describes operators for the boundaries of a rectangular domain; the respective TIBC's are nonlocal, expressing the field in the exterior as a series of Fourier modes. The method in [2] is limited to problems with a uniform exterior. This paper extends this method to structures in which half infinte straight waveguides extend from the boundary. The fields on the boundary are projected onto a modal basis associated with the waveguides, instead of on a Fourier basis. The example in Figure 1 clearly shows proper influx through a waveguide and outflux through all waveguides and into free space.

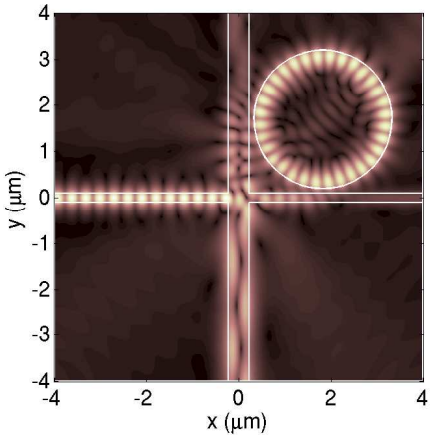

Figure 1: Finite element simulation (TE polarization, absolute value) of a waveguide crossing with a small disk. Parameters: Background refractive index 1.45, waveguide and disk refractive index 3.4, waveguide widths 0.2 μm (horizontal), 0.45 μm (vertical), disk radius 1.5 μm, gap between disk and waveguides 0.1 μm. At the boundaries fields are projected onto modes that are calculated using a window that is three times as wide as the shown finite element window. The field expansion consists of 147 terms on the western and eastern boundary and 149 on the north and south boundary.

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References

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[2] J. B. Nicolau and E. van Groesen, *Hybrid analytic-numerical method for light through a bounded planar dielectric structure*, Journal of Nonlinear Physics and Materials, **14**, 161 (2005).