Three-Dimensional Finite-Difference Time-Domain Simulation of Facet Reflection through Parallel Computing

Dmitry Labukhin, Xun Li
Department of Electrical and Computer Engineering, McMaster University,
Hamilton, ON, Canada, L8S 4K1
email: labukhd@mcmaster.ca

Precise evaluation of the facet reflection is highly desirable in design and simulation of optoelectronic devices such as super-luminescent light emitting diodes (SLEDs) and semiconductor optical amplifiers (SOAs) where ultra low facet reflection must be achieved. In this paper, the Three-dimensional (3D) Finite-Difference Time-Domain (FDTD) method has been implemented on a parallel computing algorithm for the calculation of facet reflection in optical waveguides. The result has shown that even a subtle difference in the waveguide ridge shape and facet tilting scheme has significant impact on modal reflectivity.

FDTD is the most general method to calculate the evolution of the electro-magnetic field in a region with an arbitrary refractive index profile. In particular, it can be used to model the incident and reflected fields in a truncated waveguide where the conventional Beam Propagation Method (BPM) does not apply. Traditionally, a major drawback of the FDTD approach is its memory consumption. With the rapid evolution of the computing platform, however, this problem has recently been solved through algorithms realized on high-performance computers with multiprocessors. In our implementation, the FDTD algorithm is made parallel to remove the constraint on the size of the structure imposed by the conventional method. The idea of parallel computing is to split the entire computation domain into several smaller parts. The individual parts, which each consumes less memory, are therefore treated by different processors with separate memory spaces.

An example of how a 2D mesh is split into two smaller sub-meshes is illustrated in Fig. 1. Note that the divided sub-meshes have an overlapping boundary region. The boundary grids in one sub-mesh become the inner grids of the other sub-mesh and vice versa. Therefore, after each time evolution step, the neighboring sub-meshes exchange information about the field components at the mutual boundaries, as shown in Fig. 1.

In this paper, two of the most commonly used single mode waveguides, known as the rectangular-shaped and reverse-trapezoid-shaped ridge waveguides, are considered. Two different angled-facet schemes are also investigated, where the facet plane is horizontally and vertically tilted (shown in Fig. 2a and 2b, respectively). The calculated modal reflectivity has been plotted in Fig. 3 as a function of the tilted angle for the waveguides with different ridge shapes and with differently angled facets. It is observed that the modal reflectivity of the horizontally angled facet is significantly less than that of the vertically angled facet regardless of the ridge shape. It is also found that the modal reflectivity of the rectangular-shaped ridge waveguide is always less than that of the reverse-trapezoid-shaped ridge waveguide. All of the differences are getting more pronounced as the tilted angle increases. From this simulation, it is concluded that (1) a subtle difference in waveguide terminator designs may cause a significant difference in modal reflectivity; (2) the 3D-FDTD algorithm through parallel computing is capable of handling all the structure varieties and is sufficiently accurate to capture even subtle structure differences; and (3) a horizontally tilted waveguide with rectangular-shaped ridge is the best in reducing facet reflection.

A full journal publication of this work will be published in the Journal of Computational Electronics.

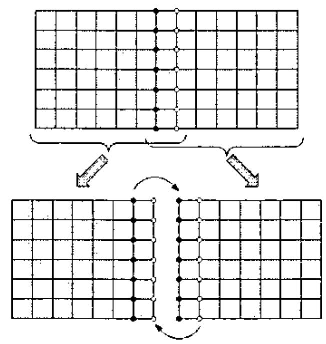

Fig. 1 Parallel computing scheme: splitting the grid into two parts. After each time evolution step, the two processors exchange information about the field calculated at these boundary grids.

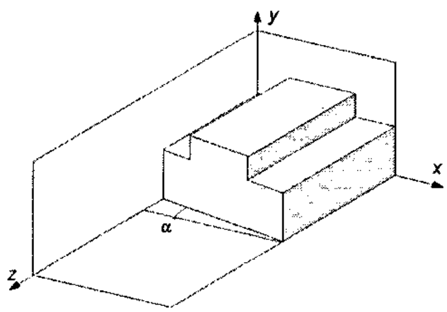

Fig. 2a Horizontally tilted facet.

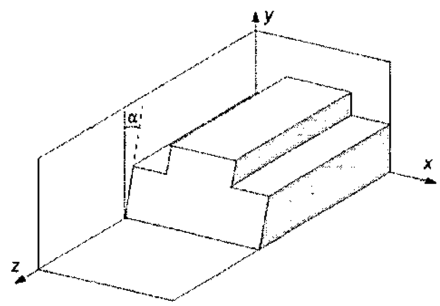

Fig. 2b Vertically tilted facet.

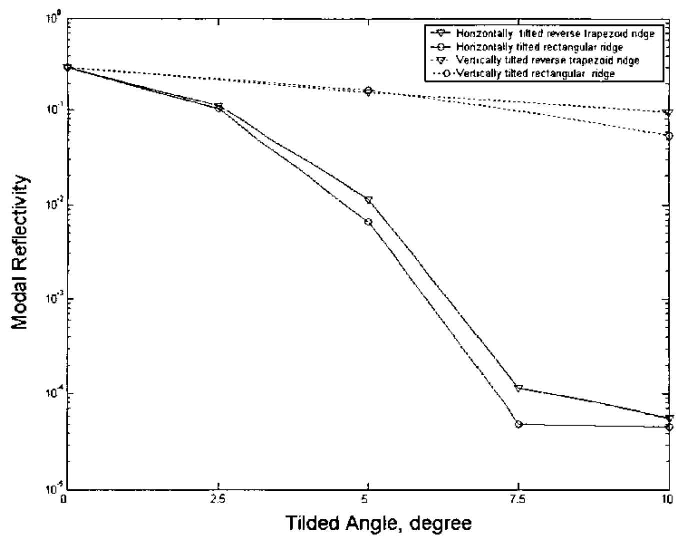

Fig. 3 Modal reflectivity as a function of tilted angle α.

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