White Paper

Design Optimization of Grating Fiber Couplers With RSoft Products

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Introduction

Optimum design of silicon photonics devices, such as grating couplers, can be achieved by numerically optimizing a large number of design parameters without in-depth knowledge of the complex underlying theories.

Optimization of the Apodized Grating

In silicon photonics, grating couplers (GCs) are essential for coupling light between optical fibers and silicon waveguides. To reduce insertion loss and achieve efficient coupling, significant effort has been made in the past, such as the inclusion of reflecting mirrors under the buried oxide (BOX) layer to stop leakage into the silicon substrate, as well as the use of apodized gratings to better match the coupled light with the fiber modal profile. The best result achieved to date is 0.58dB coupling loss, which was obtained by carefully engineering sub-wavelength photonic bandgap structures to provide the necessary refractive indices for optimum coupling [1].

With the help of Synopsys RSoft™ photonic simulation tools, complex device designs can be easily achieved by starting with simple design rules. For GCs, a simple design rule can be extracted directly from geometric optics as shown in Figure 1.

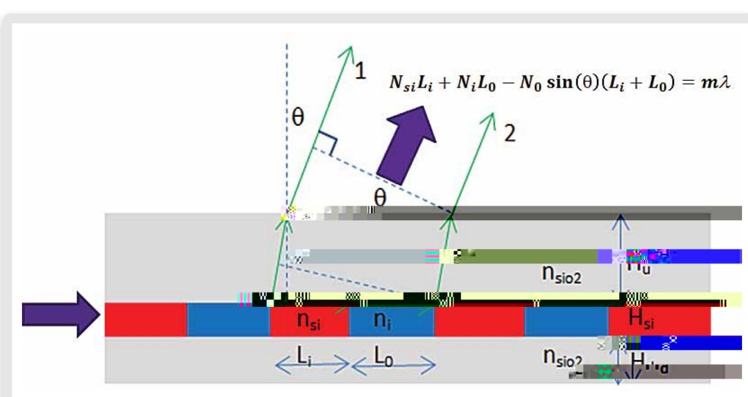

Figure 1. Schematic diagram of the coupler and phase matching condition

To maximize the coupling, the scattered light at different junctions must be in phase when it reaches the fiber. This phase-matching condition is given in Figure 1, where N_{si} and N_i are effective indices that include the oxide index, and N_0 is the index of air. Though approximated, it provides a good starting point for the optimization.

Figure 2. (a) 2D optimized index profile; (b) 2D FDTD verification, where the propagating field is shown in the inset

To effectively couple light into a fiber, we must not only match the phase, but also the fiber mode profile. The mode profile can be matched by appropriately apodizing the grating refractive index n_i. The apodization is determined by choosing the n_i's as design variables and then optimizing them, using 2D simulations, for maximum coupling efficiency. Figure 2(a) shows the resulting optimized index profile along the grating.

The simulation software used in this example is RSoft ModePROP™, which is based on the eigenmode expansion method (EME) [2]. The optimization tool used is RSoft MOST™ (Multi-variable Optimization and Scan Tool), and the optimization algorithm used is the genetic algorithm (GA). In total, 43 design parameters were optimized and about 500B(g r)-5.9-08 Tdex0B(g r)-5.9-08 Teactive in7ay9mn. I55.8(fi)2775(i7-9.5()-11.3(b.1(h)-8(e o)-8.)74D(