Abstract

This dissertation presents simulation results demonstrating that appropriate surface structuring can significantly enhance the performance of passive planar photonic components fabricated from medium-index-contrast materials (TiO_2:SiO_2/SiO_2), and, in certain cases, also in high-index-contrast structures (Si/SiO_2). Three classes of waveguide components were analyzed: circularly bent ridge waveguides, multimode interference (MMI) couplers, and TE_{00}/TE_{01} mode converters based on binary long-period gratings. The structures were modeled using the finite element method (FEM), and in the case of MMI couplers, the eigenmode expansion method (EME) was additionally employed.

The study of circularly bent waveguides were focused on two-mode structures. It was shown that a small thickness step introduced in the bend region can significantly improve their transmission characteristics by reducing excess losses, intermodal crosstalk, and bending losses of both modes. The analysis was carried out using the transformation optics formalism, which enabled the use of two-dimensional FEM simulations in the frequency domain.

In the section devoted to MMI interferometric couplers, two methods of phase error compensation based on surface structuring were proposed: a rectangular relief grating and rectangular grooves running along the lateral edges of the coupler. Proper adjustment of the geometrical parameters of these structures made it possible to significantly, or even almost completely, compensate for the phase errors of all modes involved in image formation. The lateral grooves proved effective also in couplers fabricated from materials with a high refractive index contrast.

In the final part of the work, a new method for designing TE_{00}/TE_{01} grating-based mode converters is presented. The method is based on direct numerical optimization of the structural parameters of an inhomogeneous, strongly coupled, long-period binary grating. The optimized converters achieve the required characteristics with a minimal number of segments and a minimal overall length. Their transmission properties were calculated using the matrix formalism, and the optimization was carried out with a multistart method modified by the author in the MATLAB environment. The optimized converters exhibit a record-high conversion bandwidth (up to 400 nm with conversion efficiency above 90 %) and contain no more than nine segments. The total length of these structures does not exceed 260 μm, which represents a size reduction of more than an order of magnitude compared to known solutions.

The obtained results have been partly published in four co-authored papers from the Philadelphia list and in two conference proceedings. The solutions proposed in the dissertation contribute to advancing the integration scale of planar photonic circuits fabricated from medium-index-contrast materials.