ICOCN'2021

A Compact and Low-loss TE Mode-order Converter Based on LNOI Platform

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Abstract

This paper proposes a compact and high-efficient mode converter based on Lithium-Niobate-on-isolator platform. The size of the mode converter is 8 × 3.6 μm² and the TE_0-to-TE_1 conversion efficiency is 93.46% at 1550 nm.

Structural Design and Optimization

I. An x-cut LNOI platform with a 400nm-thick (h_{LN}) LN film on a silicon oxide (SiO_2) isolation layer.
II. The cross-section of the input waveguide is depicted in Fig. 1(g) with -1.2 μm (Z_{TE0}) offset along z-direction and 0.8 μm (W_{TE0}) width.
III. The cross-section of the output waveguide is displayed in Fig. 1(h) with 0.8 μm (Z_{TE1}) offset along z-direction and 1.6 μm (W_{TE1}) width.
IV. The transition waveguide is initialized as an ellipse with the 3.1 μm major axis along the y-direction and the 2.4 μm minor axis along the z-direction.
V. The spatial accuracy of the entire simulation structure is 0.02um.
VI. The shape of the waveguide is represented by the level set method based on implicit function.
VII. The waveguide shape is optimized by the gradient descent algorithm.

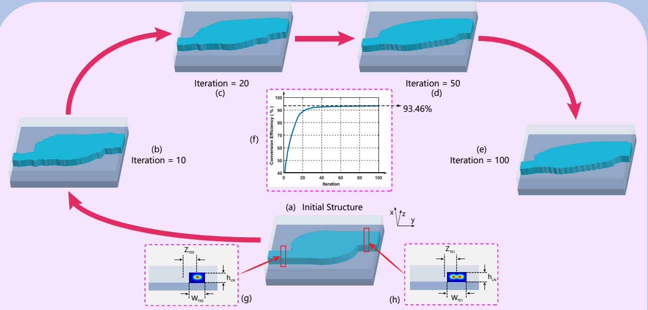

Figure 1. (a). The initial structure for optimization and the temporal structure (b). iteration = 10, (c). iteration = 20, (d). iteration = 50, (e). iteration = 100. (f). The conversion efficiency varies with the the number of iterations of the optimization algorithm. And the cross-sections of (g). input TE0 waveguide and (h). output TE1 waveguide.

References

I. D. Zhu et al., "Integrated photonics on thin-film lithium niobate," Adv. Opt. Photonics, vol. 13, no. 2, pp. 242-352, 2021.
II. H. Jia, T. Zhou, X. Fu, J. Ding, and L. Yang, "Inverse-design and demonstration of ultracompact silicon meta-structure mode exchange device," ACS Photonics, vol. 5, no. 5, pp. 1833-1838, Apr. 2018.
III. S. Fedkiw and S. Osher, "Level set methods and dynamic implicit surfaces," Appl. Mech. Rev., vol. 44, pp. 77, May 2002.
IV. Ma, W., Liu, Z., Kudyshev, Z.A. et al., "Deep learning for the design of photonic structures," Nat. Photonics, vol. 15, pp. 77–90, Oct. 2021

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Introduction

I. The photonic integration research based on the LNOI platform has been diverse for decades.
II. The study of mode-order converters based on the LNOI platform is increasingly important.
III. As the forward design is to search the optimal parameters of the geometry structure, which can be depicted briefly, the reverse design greatly expands the search range of waveguide structure with the flexible setting.

Results

I. The results of subsequent iterations oscillate and the conversion efficiency reach 93.46% after 100 iterations.
II. At 1550 nm, the insertion loss and crosstalk of the mode converter are 0.253 dB and -18.5 dB, respectively.
III. The mode converter can realize the low insertion loss (< 0.5 dB) and low crosstalk (< -13dB) in the wavelength range of 1450 nm – 1650 nm.

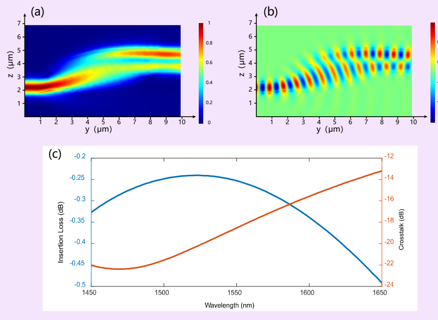

Figure 2. (a). The ultimate distribution of electric field amplitude after optimization, (b). the ultimate z-component distribution of electric field after optimization, and (c). the insertion loss and the crosstalk versus with wavelength.

Manufacture Tolerance Simulation

I. The waveguide boundary is expanded and contracted with 20nm as the first order.
II. The simulation results from shrinking by 60nm to expanding by 60nm are shown in Fig. 3(b).
III. When the waveguide boundary deviates during the range of 60nm, the overall insertion loss remains less than 0.55 dB.

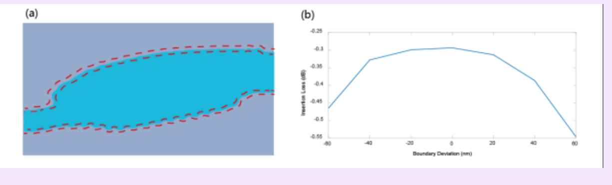

Figure 3. (a). The diagram of manufacture tolerance based on the ultimate optimization structure, (b). the results of the insertion losses under manufacture tolerance.