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Publication date:
2023

Document Version
Publisher's PDF, also known as Version of record

Inverse design of compact and broadband nanophotonic beamsplitters

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We present the development of a compact broadband silicon photonics beamsplitter using inverse design by topology optimization. The proposed device achieves an excess loss of -0.11 dB at 1550 nm, a 1-dB bandwidth of 800 nm, and return losses below -15 dB for this range.

Photonic integrated circuits (PICs) have emerged as a crucial technology for modern communication systems and sensing applications, providing a high-speed, low-power, and compact platform for integrating multiple functionalities on a chip. To fully realize their potential, each circuit component must be carefully designed to provide high performance. In this work, we utilize the inverse design method known as density-based topology optimization [1,2] to obtain a compact and broadband nanophotonic beamsplitter. We define a design domain of 2 μm × 3 μm that can transfer light from one input waveguide into two output waveguides with symmetric 3-dB splitting. We optimize for maximum transmission and minimum reflection for three wavelengths, each separated by 100 nm, to provide broadband performance.

$$\min \Phi = 10 \sum_{i=1}^{3} s_i \log_{10}\left(\frac{T_{\text{port}-} + T_{\text{port}-3}}{1+R_{\text{port}-1}}\right) / \sum_{i=1}^{3} s_i,$$

Where s_i are scaling factors, T_i are the transmissions and R_i are the back-reflections. We solve the physics in a finite-element model and the optimization with a gradient-based solver with the final design respecting the fabrication restriction of electron-beam lithography. The obtained design for a beamsplitter with a 220 nm silicon device layer embedded in glass is shown in Fig. 1 with the electric-field profile (a) and the intensity (b) for the center wavelength as well as the broadband performance (c). Compared to other design approaches [3], we achieve a larger bandwidth within a very compact footprint, which is beneficial for compact multifunctional photonic integrated circuits.

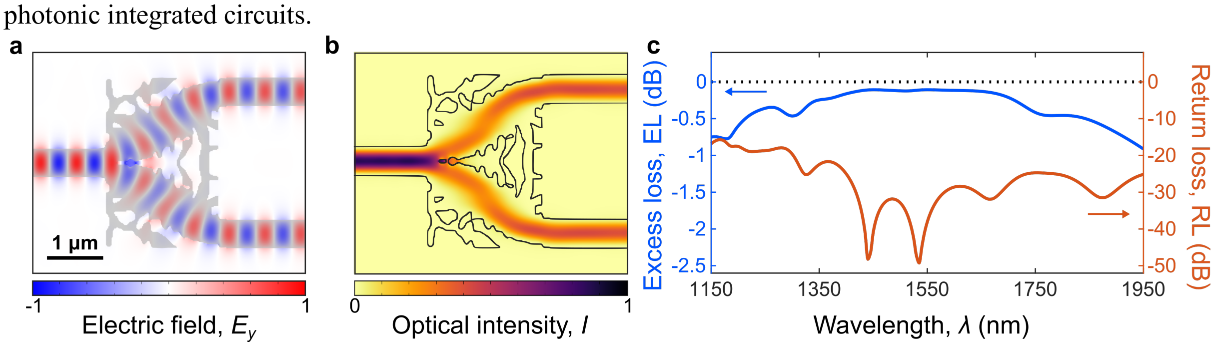

Fig. 1. A topology-optimized silicon beamsplitter with silica cladding. a. Transverse electric field (E_y). **b.** Optical intensity. **c.** Excess loss and return loss.

References

[1] R. Christiansen, O. Sigmund, *Inverse Design in Photonics by Topology Optimization: Tutorial.*, JOSA - B. 38, no. 2, p. 496-509, 2021.

[2] L. Frandsen, P. Borel, J. Jensen, O. Sigmund, *Topology Optimized Photonic Wire Splitters*, CLEO 2006 and QELS 2006, p. 1-2, 2006.

[3] D. González-Andrade, C. Lafforgue, E. Durán-Valdeiglesias, X. Le Roux, M. Berciano, E. Cassan, D. Marris-Morini, A. Velasco, P. Cheben, L. Vivien, C. Alonso-Ramos, *Polarization and Wavelength Agnostic Nanophotonic Beam Splitter*, Sci. Rep., vol. 9, no. 1, p. 3604, 2019.