



## Inverse design of compact and broadband nanophotonic beamsplitters

Hansen, Søren Engelberth; Arregui Bravo, Guillermo; Christiansen, Rasmus Ellebæk; Stobbe, Søren

*Publication date:*  
2023

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

[Link back to DTU Orbit](#)

*Citation (APA):*  
Hansen, S. E., Arregui Bravo, G., Christiansen, R. E., & Stobbe, S. (2023). *Inverse design of compact and broadband nanophotonic beamsplitters*. 1. Abstract from XXIX International Workshop on Optical Wave & Waveguide Theory and Numerical Modelling, Marseille, France.

---

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

# Inverse design of compact and broadband nanophotonic beamsplitters

Søren Engelberth Hansen<sup>1,\*</sup>, Guillermo Arregui<sup>1</sup>, Rasmus Ellebæk Christiansen<sup>2,3</sup>, Søren Stobbe<sup>1,2</sup>

<sup>1</sup> Department of Electrical and Photonics Engineering, Technical University of Denmark, Denmark

<sup>2</sup> NanoPhoton - Center for Nanophotonics, Technical University of Denmark, Denmark

<sup>3</sup> Department of Mechanical Engineering, Technical University of Denmark, Denmark

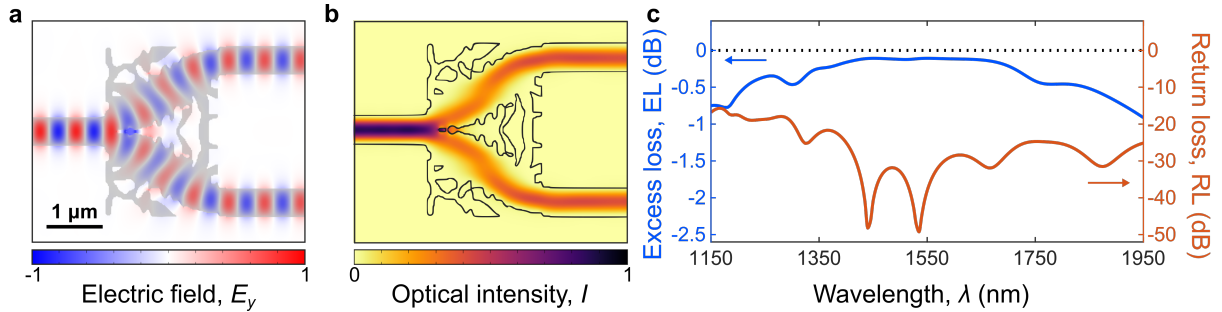
\*[senha@dtu.dk](mailto:senha@dtu.dk)

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  $2\ \mu\text{m} \times 3\ \mu\text{m}$  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.