Simple beam splitters for semi-guided waves in integrated silicon photonics

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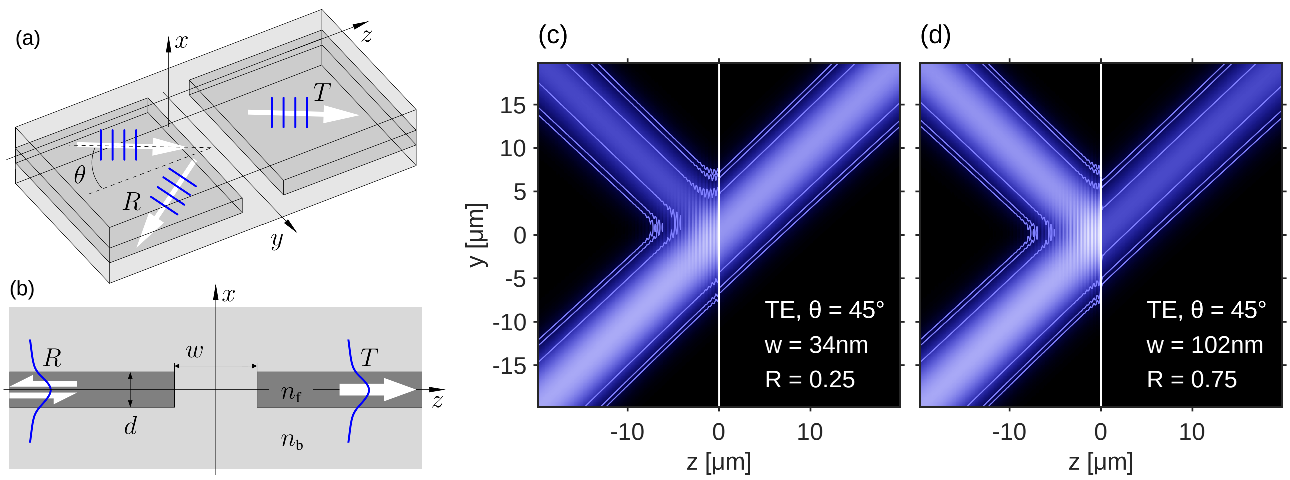
Abstract: Narrow trenches in a high-contrast silicon-photonics slab can serve as simple power dividers for semi-guided waves. The functioning relies on frustrated total internal reflection, hence one might view this as an integrated-optical variant of common macroscopic double-prism (cube) beam splitters. We discuss operation conditions where, apart from material attenuation and scattering due to surface roughness, the devices are strictly lossless [1]. Further, in a vertically symmetric configuration such as shown in the figure, polarization conversion is fully prohibited, enabling devices with mathematically “ideal” performance. The nonresonant splitters are reasonably broadband; reflectance and transmittance levels can be easily configured by selecting the width of the trenches. We numerically simulate a series of devices within the full 0-to-1-range of splitting ratios, for semi-guided plane wave incidence as well as for excitation by focused Gaussian wave bundles [2]. Straightforward cascading of the trenches leads to concepts for 1×M-power dividers and a polarization beam splitter.



Propagation of semi-guided waves towards a trench in a slab waveguide, schematic (a), and cross section view (b). Incoming waves propagate in the y-z-plane at an angle θ with respect to the trench normal, generating outgoing waves with reflectance R and transmittance T. Parameters: refractive indices $n_b = 1.45$ (background), $n_f = 3.45$ (film), slab thickness $d = 0.22\,\mu$m, trench width w, target vacuum wavelength $\lambda = 1.55\,\mu$m. (c, d): Power dividers of width w; excitation by TE-polarized semi-guided Gaussian wave bundles of a cross-sectional width of $7\,\mu$m at angle θ leads to a reflectance R and transmittance $T = 1 - R$; energy density of the optical electromagnetic field, contour lines at 5%, 1%, and 0.5% of the maximum level.

References

[1] M. Hammer, L. Ebers, A. Hildebrandt, S. Alhaddad, and J. Förstner. Oblique semi-guided waves: 2-D integrated photonics with negative effective permittivity. In *2018 IEEE 17th International Conference on Mathematical Methods in Electromagnetic Theory (MMET)*, pages 9–15, 2018.

[2] M. Hammer, L. Ebers, and J. Förstner. Configurable lossless broadband beam splitters for semi-guided waves in integrated silicon photonics. *OSA Continuum*, 4(12):3081–3095, 2021.