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 $1 \times M$-power dividers and a polarization beam splitter.

![Diagram of beam splitter](attachment:image.png)

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 $\theta$ 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 $\theta$ 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**
