Oblique quasi-lossless excitation of a thin silicon slab waveguide

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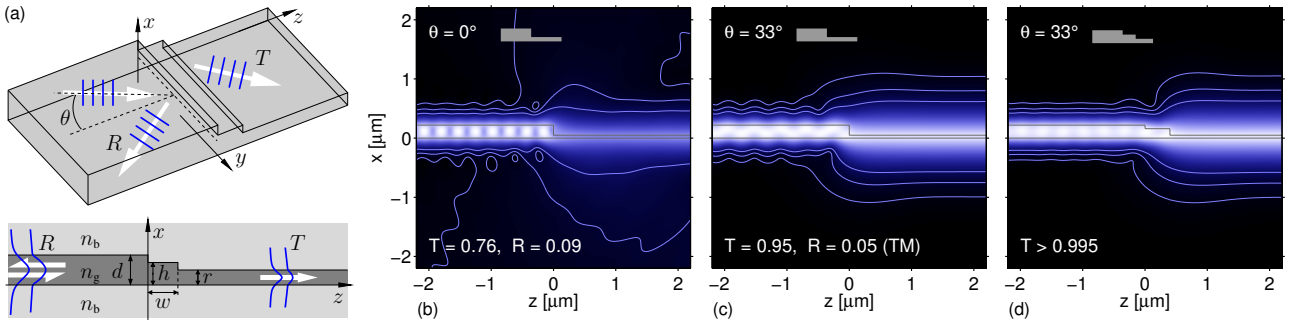
Radiation losses at a junction of high-contrast Si/SiO_2-slabs can be avoided, if, for semi-guided waves, the angle of incidence is raised beyond a critical angle. By introducing an additional segment of intermediate thickness, reflections can be suppressed; our simulations predict near-full transmittance for the "coated" interface.

Interfacing slab waveguides of different thickness

In a traditional 2-D setting, guided waves traversing an abrupt interface between different slab waveguides typically generate more or less pronounced reflections and scattering losses. High-contrast silicon slabs are considered, as introduced in part (a) of the figure. The field (b) relates to the standard setting, with normal incidence of the guided TE wave. Applying a semi-analytical vectorial mode expansion solver [1] for the effective 2-D problems, we now investigate what happens when the waves come in at oblique angles. Arguments based on a variant of Snell's law, adapted to the present case of polarized semi-guided waves, predict critical angles of incidence, beyond which all scattering losses are suppressed. In that regime (c), the transmittance is already raised to about 95%. The waves, however, are still partly reflected, mainly into the backwards TM mode.



Artists impression and cross section view (a) of the waveguide interface. Single-mode Si/SiO_2-waveguides of thicknesses $d = 0.22\,\mu$m and $r = 0.05\,\mu$m are considered, with refractive indices $n_g = 3.45$ and $n_b = 1.45$, at a wavelength of $1.55\,\mu$m. Transmittances T and reflectances R are given for semi-guided TE excitation at angle θ. Results for abrupt interfaces at normal (b) and oblique incidence (c), and for a "coated" interface (d), with a segment of height $h = 0.16\,\mu$m and width $w = 0.4\,\mu$m, are shown. The plots relate to the absolute magnetic field $|\boldsymbol{H}|$ in the x-z cross section plane, with contours at 2%, 5%, and 10% of the maximum levels.

A guided-wave-variant of an anti-reflection coating

Motivated by the traditional technique of reflection suppression, we introduce a short waveguide segment of intermediate thickness at the former interface. Optimization of the transmittance through varying the height and width of that segment leads to configuration (d) with a guided-wave TE-to-TE transmittance above 99.5%. Rigorous finite-element simulations (COMSOL) confirm these findings.

Reference

[1] M. Hammer. Oblique incidence of semi-guided waves on rectangular slab waveguide discontinuities: A vectorial QUEP solver. *Optics Communications*, 338:447–456, 2015.