Lossless operation of high-contrast integrated optical waveguide gratings

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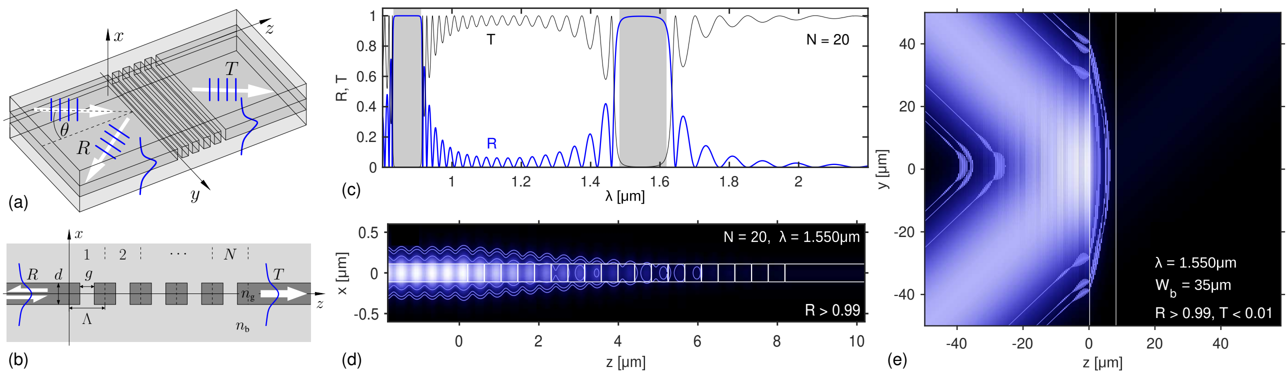
Radiative losses in slab waveguide Bragg gratings of high index contrast can be fully suppressed, if these are excited by oblique semi-guided waves at large angles of incidence. For symmetric gratings, also polarization conversion is forbidden. Structures with parameters from silicon photonics serve as examples.

Oblique excitation of slab waveguide Bragg gratings

Wave propagation along finite waveguide gratings with high refractive index contrast and/or large corrugation depths tends to be accompanied by radiative losses, which are highly unwanted for applications such as optical signal-processing filters, sensors, or lasing reflectors. In that context, we explore the properties of gratings with simple rectangular corrugations and 1-D periodicity, as exemplified in the figure. The structures are excited by "semi-guided waves" that are strictly confined in the direction perpendicular to the guiding slab, that have in-plane the form of a plane wave, and that come in at the grating at an oblique angle. We show that, for a sufficiently high angle of incidence, radiation losses, originating either from the corrugated region or from the interfaces between the grating and the original slab, are (mathematically) strictly suppressed. In the band-structure analysis, the concept of a "light line" does not apply. Further, by virtue of symmetry arguments, polarization conversion is strictly prohibited.

Results for a series of fully- and partly-etched finite gratings are discussed, for SiO_2-embedded silicon slabs, specifically for TE excitation at an angle of 45°. The devices generate a reasonably flat-top wavelength response; apodization can lead to even more box-shaped spectra. TE transmittance and reflectance add up to one in all cases. Together with a narrow-band Fabry-Perot filter based on similar principles, these configurations exhibit reflection bands, or transmittance peaks, with widths that span three orders of magnitude.



A symmetric slab waveguide grating, schematic (a), and cross-section view (b). Results for $N = 20$ periods, refractive indices $n_b = 1.45$, $n_g = 3.45$, thickness $d = 0.22\,\mu$m, period $\Lambda = 420$ nm, gap $g = 10$ nm, and incoming semi-guided TE waves at angle $\theta = 45°$: Reflectance R and transmittance T versus wavelength λ (c), energy density for plane wave excitation (d), and for excitation by a beam of width W_b (e), at $\lambda = 1.55\,\mu$m. (Figure adapted from Ref. [1])

References

[1] M. Hammer, H. Farheen, and J. Förstner. How to suppress radiative losses in high-contrast integrated Bragg gratings. Submitted for publication, 2023.