Reflection of semi-guided plane waves at angled thin-film transitions

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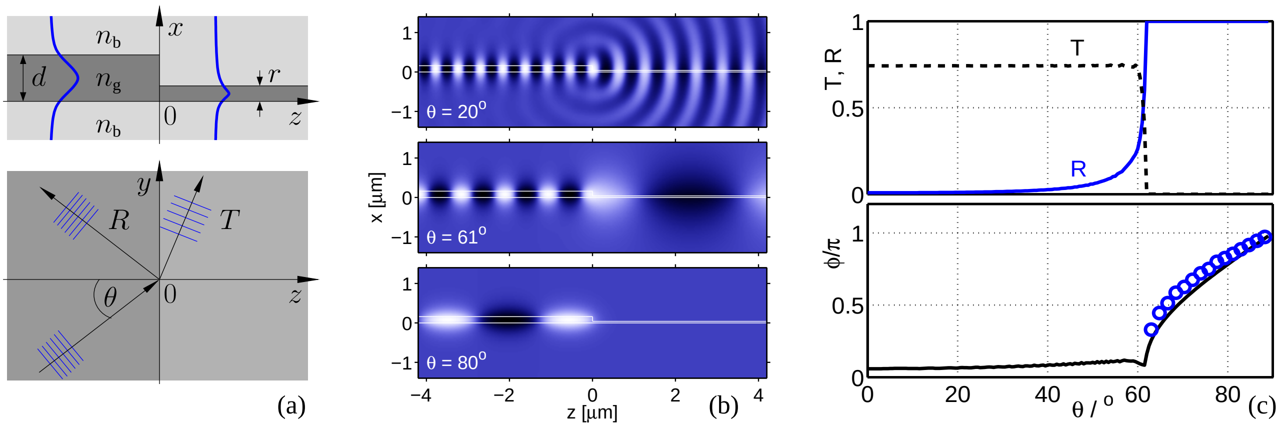
The propagation of thin-film guided, in-plane unguided plane optical waves, and their partial or total reflection at transitions between regions with different film thickness, is considered. The properties of reflected and refracted waves can be predicted reasonably by readily available Helmholtz- and/or eigenmode-solvers.

2-D optics

Classical concepts [1] for integrated optical components like mirrors, lenses, prisms, polarizers, but also for entire spectrometers [2], rely on the effects that a — tapered or step-like — transition between regions with different layering, specifically different core thickness, has on thin-film guided, in-plane unguided light. Results for the reflection and refraction of 1-D guided plane waves at such a discontinuity may form the basis for a description of the in-plane propagation by geometrical optics [1, 2]. Part (a) of the figure below shows a typical configuration. As a step beyond the classical effective index picture, we will discuss and compare two approaches on how this problem can be tackled — at least partly — by standard tools for integrated optics design.

(I) Accepting the scalar approximation, using an ansatz of a uniform harmonic field dependence on the interface coordinate y, the 3-D problem reduces to a 2-D Helmholtz problem, for guided wave input and transparent boundaries, where the permittivity depends on the incidence angle.

(II) By complementing the x-z-view with a mirrored interface at some faraway negative z-position, one obtains the 2-D cross section of a wide multimode rib channel. Constraints for transverse resonance permit to translate the propagation constants of its polarized modes into discrete samples of the phase factors experienced by an in-plane guided wave upon total internal reflection at the sidewalls.



(a): Reflection of semi-guided plane waves at a thin film step discontinuity. (b): Snapshots for wave incidence at different angles θ. (c): Transmittance T, reflectance R, and phase shift ϕ upon reflection vs. incidence angle θ, predicted by a 2-D Helmholtz solver (I), and by mode analysis (II, markers) of an $8\,\mu$m wide rib. Parameters, cf. (a): $n_b = 1.4524$, $n_g = 2.0081$, $d = 160$ nm, $r = 40$ nm, TE-fields, vacuum wavelength $\lambda = 850$ nm.

References

[1] P. K. Tien. *Rev. Mod. Phys.*, 49(2):361, 1977; R. Ulrich, R. J. Martin, *Appl. Opt.*, 10(9):2077, 1971.
[2] F. Çivitci, H. J. W. M. Hoekstra. Europ. Conf. Integr. Optics (ECIO), Barcelona, Spain, paper 151, 2012.

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