Dielectric waveguides with shallow ribs — symmetry-protected TM modes

Candidate: — requested —
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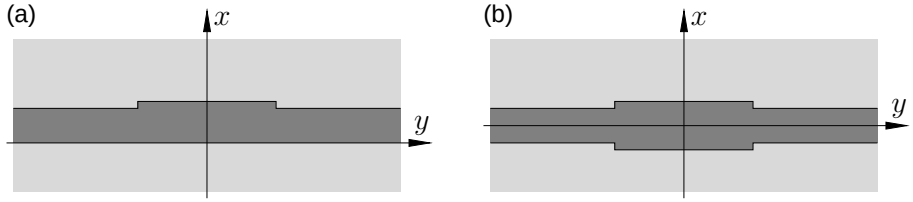
Dielectric channel waveguides with rib-shaped cross sections as in part (a) of the figure are frequently used in integrated optical circuits. Depending on the etching depth, or the rib height, respectively, these support guided modes of TE- and / or TM-like polarizations. Usually, a certain minimum rib height is required for a truly guided TM mode to exist. At insufficient etching depth, leaky modes with TM-like polarization can be supported; further, there exist certain rib widths ("magical widths"), at which these leaky TM modes are "nearly" guided, i.e. show very low leakage losses only.



Dielectric waveguides with shallow etching, cross sections, standard configuration (a) and a symmetric structure with a "double" rib (b). Light propagates in the direction z along the waveguide axis (not shown), perpendicular to the x-y-cross sectional plane.

According to arguments adopted recently in a slightly different context [1, 2], we anticipate that a similar symmetric structure (b) with an additional downward oriented rib should support truly guided TM modes *irrespectively* of the etching depth. It is the purpose of this project to check and further develop this hypothesis by numerical means.

Tentative program, certainly negotiable and to be adapted according to the progress of the work, and not necessary in the order as given:

- Clarify the theoretical background of the problem in question.
- Prepare a rough literature survey: Have waveguides with a cross section as in (b) been investigated already in somewhat more detail, and with respect to the TM leakage? Potential keywords: optical rib waveguides, guided / leaky modes, lateral leakage, minimum etching depth, magical width, symmetry, shallow rib height, . . .
- Establish a numerical model for the analysis of guided and leaky modes (COMSOL), for waveguides of types (a) and (b). Adopt typical parameters from silicon photonics (refractive indices, film thickness, telecom wavelength).
- Characterize numerically a series of waveguides of type (a), concerning etching depth and rib width, for TE- and TM polarization. Look for guided and leaky modes, and for the "magical widths".
- Characterize numerically a series of waveguides of type (b), concerning etching depth and rib width, for TE- and TM polarization. Look for guided and leaky modes. Are guided TM modes supported in all cases?
- If yes: Analyze the stability of such "symmetry protected" guided modes, e.g. what concerns small deviations from the symmetric configuration.
- Report on your findings; prepare a respective presentation.

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[1] *Configurable lossless broadband beam splitters . . .*, OSA Continuum 4 (2), 3081–3095 (2021)
[2] *How to suppress radiative losses in high-contrast integrated Bragg gratings*, JOSA B (accepted, 2023)