Guided modes of dielectric slab waveguides with anisotropic core

Candidates: — requested —
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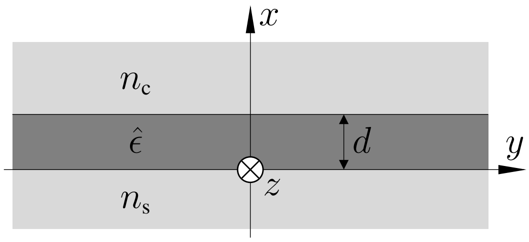
Embedding: Theoretical Electrical Engineering (TET)

Dielectric slab waveguides, and the guided modes supported by these, constitute one of the fundamental concepts for the design of integrated photonic circuits. We consider a simple three-layer slab waveguide, with an anisotropic core layer, made of a birefringent medium, as shown schematically in the figure. This project aims at establishing a mostly analytical solver for the guided modes supported by waveguides of this kind, for a specific kind of anisotropy.



Slab waveguide: A potentially anisotropic core of thickness d with relative permittivity $\hat{\epsilon}$ is sandwiched between isotropic half-infinite substrate and cladding media with refractive indices n_s and n_c. The structure is constant along the in-plane directions y and z; x indicates the direction perpendicular to the slab. Field solutions are sought that are constant along y; light propagates along the z-axis, in the form of possibly vectorial guided modes with profiles that depend on x only.

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 of the problem in question, first for an isotropic core ($\hat{\epsilon} = n_\mathrm{f}^2 \hat{1}$): Maxwell equations in the frequency domain for uncharged, linear, nonmagnetic, and lossless media, conditions for the continuity of the electromagnetic fields at dielectric interfaces, ansatz for guided modes, solution procedure. Examples: [1].
- Specialize to a core made of birefringent lithium-niobate material [2, assistance from your supervisors]. Consider alternatively X-cut and Z-cut configurations, with potentially oblique alignment of the in-plane crystal axes with respect to the waveguide coordinate system (as introduced in the figure), i.e. with respect to the direction of wave propagation. Specify the respective permittivity tensors $\hat{\epsilon}$.
- Prepare a rough literature survey: Can you find papers on the guided modes supported by slab waveguides as discussed before?
- Extend your former theoretical description to the case of the anisotropic, birefringent core medium. All aspects of the former model need to be revised carefully.
- Implement the solver in a program language of your choice (e.g. MATLAB); procedures for numerical root finding will be required.
- Test your solver first for isotropic waveguides, use [1] as a reference.
- Run your solver for a series of anisotropic waveguides. Parameters will be provided by your supervisors. Of interest: Dependence of effective indices on waveguide thickness, at one or two target wavelengths, for crystal axis-aligned wave propagation, and as a function of the angle between the in-plane crystal axes and the modal propagation axes, for X-cut and Z-cut slabs. Characterize the polarization of the guided modes in a suitable way. Compare with results from the literature, if possible.
- Report on your findings; prepare a respective presentation.

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[1] *OMS*, www.siio.eu,

[2] A. Yariv and P. Yeh, *Optical Waves in Crystals: Propagation and Control of Laser Radiation*, Wiley, New York, 1984.