Guided modes of Lithium-Niobate channel waveguides with anisotropic cores

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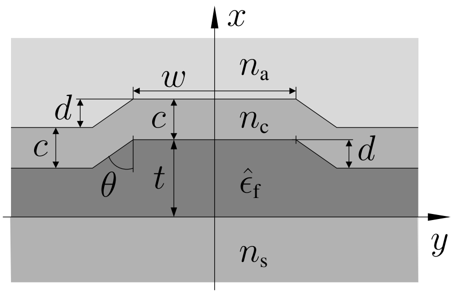
Embedding: Theoretical Electrical Engineering (TET)

Dielectric channel waveguides, and the guided modes supported by these, constitute one of the fundamental components of integrated photonic circuits. We consider a specific type of LNOI waveguides, with cross sections as shown in the figure. The waveguides are fabricated on the basis of a crystalline core medium, where the orientation of the waveguide, relative to the optical axes of the anisotropic (birefringent) core, influences the guidance properties of the structures. This project aims at rigorous numerical investigations of the guided modes supported by these channels, and in particular their polarization, as a function of the waveguide orientation relative to the crystal.



Waveguide cross section; A potentially anisotropic core of thickness t and width w, with etching depth d, sidewall angle θ, and with relative permittivity $\hat{\epsilon}_f$, is sandwiched between isotropic substrate and cladding media (thickness c) with refractive indices n_s and n_c, with an air cover (n_a). Coordinates x and y span the waveguide cross section plane, light propagates along the z-axis perpendicular to that plane. The channel is constant along z.

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, first for an isotropic core ($\hat{\epsilon} = n_f^2 \hat{1}$): Maxwell equations in the frequency domain for uncharged, linear, nonmagnetic, and lossless media, ansatz for guided modes, rough survey of their properties. Refer to standard textbooks on integrated optics / optical waveguide theory.
- Get familier with the COMSOL simulation environment [1], specialize to the modal analysis of dielectric channel waveguides (2-D eigenvalue problem).
- Set up a model for simpler rectangular dielectric channel waveguides. Carry out a modal analysis; compare with reference results.
- Consider a core made of birefringent lithium-niobate material [2, assistance from your supervisors], alternatively X-cut and Z-cut configurations, with potentially oblique alignment of the in-plane crystal axes with respect to external coordinates, i.e. the later waveguide coordinate system. Specify the respective permittivity tensors $\hat{\epsilon}_f$.
- Extend your COMSOL model to waveguides with a cross section as shown in the figure, with anisotropic core, with potentially oblique alignment of the direction of propatation with respect to the axes of the core crystal.
- Carry out a series of modal analysis runs, in particular for waveguides of varying width, for different waveguide orientations. Characterize the polarization properties of the hybrid, vectorial modes.
- Report on your findings; prepare a respective presentation.

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[1] *COMSOL*, Comsol Multiphysics GmbH, Göttingen, Germany,
[2] A. Yariv and P. Yeh, *Optical Waves in Crystals: Propagation and Control of Laser Radiation*, Wiley, New York, 1984.