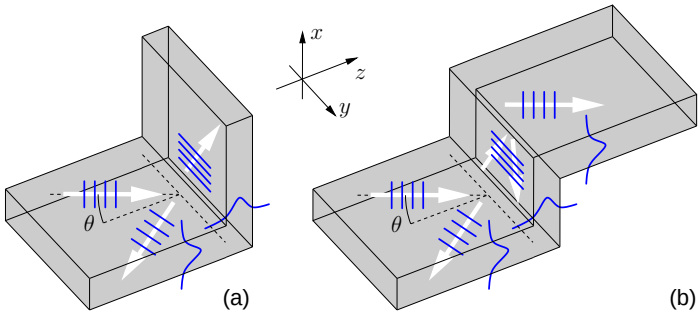
Oblique semi-guided waves: Modeling quasi-2-D waveguide optics with COMSOL

Candidate: — requested —
Supervisors: Manfred Hammer, Yao Kou, Jens Förstner
Embedding: Theoretical Electrical Engineering (TET)



Semi-guided waves confined in dielectric slab waveguides are being considered, for oblique angles of propagation. If the waves encounter a linear discontinuity of quite arbitrary shape and extension, a variant of Snell's law applies, separately for each pair of incoming and outgoing modes. Depending on the effective indices involved, and on the angle of incidence, power transfer to specific outgoing waves can be allowed or forbidden. In particular, critical angles of incidence can be identified, beyond which any power transfer to non-guided waves is forbidden, i.e. all radiative losses are suppressed. In that case the input power is carried away from the discontinuity exclusively by reflected semi-guided waves in the input slab, or by semi-guided waves that are transmitted into other outgoing slab waveguides. As examples, the figure shows structures with corner- (a) or step-shaped (b) discontinuities.

Vectorial equations on a 2-D cross sectional domain apply, with transparent-influx boundary conditions. A semianalytical solver for problems of this kind exists [1], which has been applied successfully to the former corner and step structures [2]. Unfortunately, due to the type of analytical expansions employed, that solver is rather restricted in its applicability.

So what about tackling the 2-D oblique-wave scattering problem by numerical means?

In this project we plan to explore a larger range of (in particular non-rectangular) structures using the frequency-domain finite-element solvers included in the COMSOL-Multiphysics Modeling Software.

Tentative program, negotiable and to be adapted according to the progress of the work:

- Make yourself familiar with the theoretical background of the problem in question.
- Establish 2-D frequency-domain models in COMSOL for
  - plane wave reflection at a dielectric interface, for oblique incidence (reference: Fresnel-equations),
  - oblique mode propagation along dielectric slab waveguides (reference: analytical solution)
  - the corner- and step-configurations of Ref. [2],
  - bent slab waveguides, as discussed in [3], incl. the transition to/from a straight access waveguide,
  - other potentially interesting structures.
- Laterally confined 3-D solutions can be obtained as superpositions of the former 2-D fields [2]. Assemble respective wave bundles as wavenumber-integrals of numerical 2-D fields exported from COMSOL, for each of (some of) the former structures.
- Finally, laterally guiding configurations could be considered, with (slightly) increased refractive index along the path of the previous bundles . . . ?

If you think that you might like a theoretical task in between Applied Physics, Applied Mathematics, and Electrical Engineering, then don't hesitate to contact us!

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[1] M. Hammer, *Oblique incidence of semi-guided waves on rectangular slab waveguide discontinuities: A vectorial QUEP solver*, Optics Communications **338**, 447-456 (2015),

[2] M. Hammer, A. Hildebrandt, J. Förstner, *Full resonant transmission of semi-guided planar waves through slab waveguide steps at oblique incidence*, Journal of Lightwave Technology 34 (3), 997-1005 (2016)

[3] L. Ebers, M. Hammer, J. Förstner, *Spiral modes supported by circular dielectric tubes and tube segments*, Optical and Quantum Electronics (submitted, 2017)