Optical Waveguide Theory (A)

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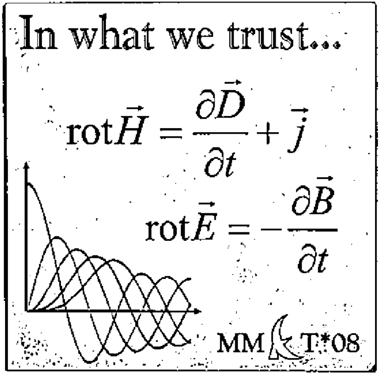
Motto



MMET'08, Mathematical Methods in Electromagnetic Theory
Odesa, Ukraine, June 29 – July 2, 2008

Maxwell equations

SI, in matter, time domain, differential form:

$$
\begin{aligned}
\boldsymbol{\nabla} \cdot \boldsymbol{D} &= \rho_{\mathrm{f}}, \\
\boldsymbol{\nabla} \times \boldsymbol{E} &= -\dot{\boldsymbol{B}}, \\
\boldsymbol{\nabla} \cdot \boldsymbol{B} &= 0, \\
\boldsymbol{\nabla} \times \boldsymbol{H} &= \boldsymbol{J}_{\mathrm{f}} + \dot{\boldsymbol{D}}, \\
\\
\boldsymbol{D} &= \epsilon_0 \boldsymbol{E} + \boldsymbol{P}, \\
\boldsymbol{B} &= \mu_0 (\boldsymbol{H} + \boldsymbol{M}).
\end{aligned}
$$

(+ constitutive relations)

- $\boldsymbol{E}(\boldsymbol{r}, t)$: electric field,
- $\boldsymbol{D}(\boldsymbol{r}, t)$: (di-)electric displacement,
- $\boldsymbol{B}(\boldsymbol{r}, t)$: magnetic induction (field, flux density),
- $\boldsymbol{H}(\boldsymbol{r}, t)$: magnetic field (...),
- $\rho_{\mathrm{f}}(\boldsymbol{r}, t)$: density of free charges,
- $\boldsymbol{J}_{\mathrm{f}}(\boldsymbol{r}, t)$: density of free currents,
- $\boldsymbol{P}(\boldsymbol{r}, t)$: polarization,
- $\boldsymbol{M}(\boldsymbol{r}, t)$: magnetization,
- ϵ_0: free space permittivity,
- μ_0: free space permeability.

Valid for more than a century, firm basis for further considerations.

Course overview

Optical waveguide theory

A Photonics / integrated optics; theory, motto; phenomena, introductory examples.

B Brush up on mathematical tools.

C Maxwell equations, different formulations, interfaces, energy and power flow.

D Classes of simulation tasks: scattering problems, mode analysis, resonance problems.

E Normal modes of dielectric optical waveguides, mode interference.

F Examples for dielectric optical waveguides.

G Waveguide discontinuities & circuits, scattering matrices, reciprocal circuits.

H Bent optical waveguides; whispering gallery resonances; circular microresonators.

I Coupled mode theory, perturbation theory.

- Hybrid analytical / numerical coupled mode theory.

J A touch of photonic crystals; a touch of plasmonics.

- Oblique semi-guided waves: 2-D integrated optics.
- Summary, concluding remarks.

Formalities

Organization of the course:

- Lectures ($\approx 13\times$)
- Homework ($7\times$)
- Tutorials ($6\times$)
- Exercises classes ($6\times$)
- Exam

Related textbooks (examples):

C. Vassallo, *Optical Waveguide Concepts*, Elsevier, Amsterdam (1991),
K. Okamoto, *Fundamentals of Optical Waveguides*, Academic Press, San Diego, USA (2000),
R. März, *Integrated Optics: Design and Modeling*, Artech House, Norwood, USA (1995),
A.W. Snyder, J.D. Love, *Optical Waveguide Theory*, Chapman and Hall, London, UK (1983);

& general introductory texts on classical electrodynamics.

Optical waveguides: phenomena, examples

- Beam propagation in free space
- Guided light propagation
- Waveguide end facet
- Crossing of two waveguides
- Modes of 1-D multilayer slab waveguides
- Modes of 2-D channel waveguides
- Evanescent coupling between waveguides
- Bent waveguides
- Circular microring-resonator
- Microdisk resonator
- CROW
- Waveguide corner
- Photonic crystal waveguide
- Exciting TET !

Optical waveguide "theory"

Task: solve

$$\begin{aligned} \boldsymbol{\nabla}\times\boldsymbol{E} &= -\dot{\boldsymbol{B}}, & \boldsymbol{\nabla}\cdot\boldsymbol{D} &= \rho_\mathrm{f}, & \boldsymbol{D} &= \epsilon_0\boldsymbol{E}+\boldsymbol{P}, \\ \boldsymbol{\nabla}\times\boldsymbol{H} &= \boldsymbol{J}_\mathrm{f}+\dot{\boldsymbol{D}}, & \boldsymbol{\nabla}\cdot\boldsymbol{B} &= 0, & \boldsymbol{B} &= \mu_0(\boldsymbol{H}+\boldsymbol{M}), \quad (\& \ \ \ldots). \end{aligned}$$

In this course:

- specialization to problems relevant for integrated optics,
- theoretical basis for the — mostly — numerical solution,
- approximate concepts,
- examples.

Upcoming

Next lectures:

- Brush up on mathematical tools.
- Maxwell equations, different formulations, interfaces, energy and power flow.
- Classes of simulation tasks: scattering problems, mode analysis, resonance problems.