Advanced Optics (NOOE139)

„advanced" =

- repeat fundamentals (*Maxwell's eqs*),
- provide alternative view (*geometric optics, polarization*),
- wider context (*diffraction, coherence*),
- and try new stuff (*Fourier optics, Gaussian beams*)

formalities:

- 3 hours lecture + 2 hours tutorials per week
- 12x Wednesday + 13x Thursdays (~ 12 full lectures)
- Oral exam from the lecture's whole scope
- Tutorial requirement:
  - Score >50% from a written test (before Christmas)

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	1 7:20	2 8:10	3 9:00	4 9:50	5 10:40	6 11:30	7 12:20	8 13:10	9 14:00	10 14:50	11 15:40	12 16:30	13 17:20	14 18:10	15 19:00	16 19:50
Mo			Náhradní výuka Advance Nádvorník Lukáš, RNDr., M6 9:00 - 10:30													
Tu			Náhradní výuka Advanced Optics 4.10.2 Nádvorník Lukáš, RNDr., Ph.D. M3 9:00 - 11:25													
We									**Advanced optics** Nádvorník Lukáš, RNDr., Ph.D. M5 14:00 NOOE139							
Th									*Advanced optics* Nádvorník Lukáš, RNDr., M3 14:00 NOOE139							
Fr																

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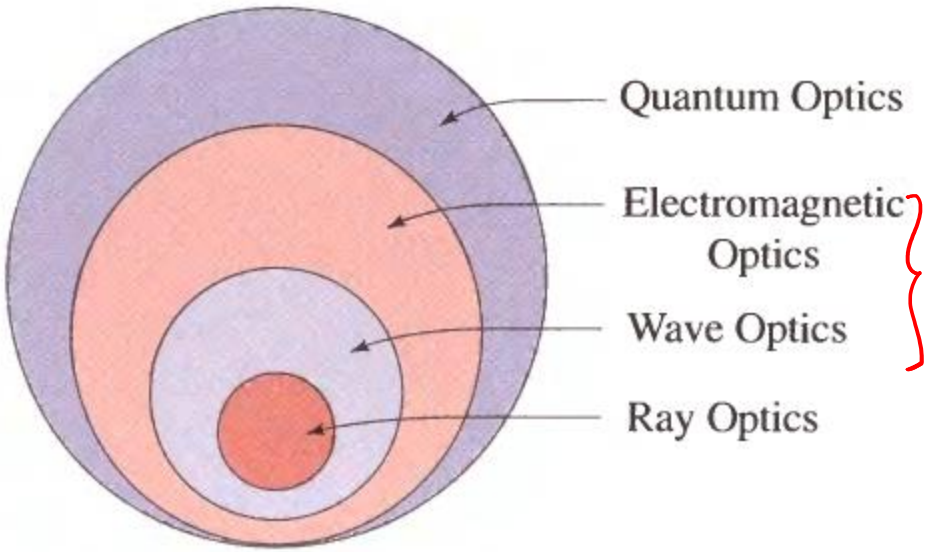
- B. E. A. Saleh, M.C, Teich: *Fundamentals of Photonics*, John Wiley & sons, inc., New York, 1991.
- E. Hecht: *Optics*, Addison Wesley, 4th edition, San Francisco. 2002.
- M. Born, E. Wolf: *Principles of Optics*, Cambridge University Press, 7th extended edition, Cambridge 2003.
- J. Peatross and M. Ware: *Physics of Light and Optics*, 2015 edition, available at optics.byu.edu/textbook
- F. L. Pedrotti: *Introduction of Optics*, Pearson, Upper Saddle River, N. J., 2007.

Approximations



no single-photon counting, no quantum effects

scalar fields, no E-B coupling, often material described by *n*

λ << objects, infinite *c*, often paraxial approximation (small angles)

Syllabus

Syllabus:

1. Basic equations of electromagnetic theory.

- Electromagnetic origin of light, Maxwell equations, boundary conditions.
- Wave equation, Helmoltz equation. Phase and group velocity of light.
- Energy, intensity, radiation pressure and momentum of electromagnetic wave.

2. Polarization of light.

- Polarization ellipse, linear and circular polarization. Angular momentum of electromagnetic wave.
- Propagation of light in anisotropic media. Polarization devices – polarizers, wave plates, polarization rotators.
- Mathematical description of polarization – Jones vectors and matrices, Stokes parameters, Poincaré sphere.

3. Instrumental optics.

- Geometrical optics, light rays. Optical imaging by reflection and refraction on a spherical interface, mirrors, lenses. Ray transfer matrix analysis. Aberrations (monochromatic and chromatic).
- Fresnel and Fraunhofer diffraction on slit, rectangular and spherical aperture; implications for a construction of optical instruments. Optical diffraction grating.
- Optical imaging instruments (magnifier glasses, microscope, telescope). Spectral instruments - spectrometers (prism and grating) and interferometers.

4. Light waves in absorbing medium.

- Propagation of light in conductive medium, complex index of refraction.
- Reflection and refraction of plane waves on interfaces, Fresnel formulae.
- Kramers-Kronig dispersion relation.

5. Introduction to theory of optical coherence.

- Complex representation of monochromatic and polychromatic waves, Fourier transformation, complex analytical signal. Statistical optics, ergodicity principle.
- Time coherence, correlation function, power spectrum, Wiener-Chinčin theorem. Spatial coherence.
- Interference of partially coherent light, Michelson interferometer, Fourier spectrometers.
- Partial polarization, coherence matrix, degree of polarization.

6. Fourier optics.

- Two-dimensional Fourier transformation, spatial frequencies.
- Optical transfer function of imaging system, impulse response.
- Optical computation of Fourier transform, spatial filtration.

7. Gaussian beams and optical resonators.

- Paraxial Helmholtz equation. Gaussian beam - complex amplitude, intensity, radius, divergence, wavefronts. Transformation of Gaussian beam by optical elements, ABCD law.
- Optical resonators – resonant frequencies, longitudinal and transversal modes. Losses in resonators. Boyd-Kogelnik stability diagram.

Basic equations of electromagnetic theory

charge dens.

(1) $\mathrm{div}\,\vec{D} = \rho$ $\qquad$ $\mathrm{div}\,\vec{B} = 0$ (2) $\quad \}$ div eq

(4) $\underbrace{\mathrm{rot}\,\vec{H} - \frac{\partial \vec{D}}{\partial t} = \vec{j}}_{\text{source eqs.}}$ $\qquad$ $\mathrm{rot}\,\vec{E} + \frac{\partial \vec{B}}{\partial t} = 0$ (3) $\quad \}$ coupling

electric current dens.

curl $\leftrightarrow$ rot ... $\vec{\nabla}\times$

div ... $\vec{\nabla}\cdot$

$\vec{\nabla} = \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right)$

$\vec{E}$: el. field $[\mathrm{V\,m^{-1}}]$

$\vec{H}$: mg. field $[\mathrm{A\,m^{-1}}]$

$\vec{D}$: el. flux density $[\mathrm{C\,m^{-2}}]$ "electric displacement"

$\vec{B}$: mg. flux dens. $[\mathrm{T}]$

$\vec{j}$: el. curr. dens. $[\mathrm{A\,m^{-2}}]$

ρ : el. charge dens. $[\mathrm{C\,m^{-3}}]$

$\rightarrow \quad \vec{D} = \overleftrightarrow{\varepsilon}\,\vec{E}$

permittivity tensor

$\overleftrightarrow{\varepsilon} = \varepsilon_0 \overleftrightarrow{\varepsilon}_r \qquad \varepsilon = \varepsilon_0$

$$\begin{pmatrix} \varepsilon_{11} & \varepsilon_{12} & \cdots \\ - & - & \cdot \\ - & - & - \end{pmatrix}$$

polarization $\quad$ Polarizability

$\vec{D} = \varepsilon_0 \overleftrightarrow{\varepsilon}_r \vec{E} = \varepsilon_0 \vec{E} + \vec{P} = \varepsilon_0 \vec{E} + \overleftrightarrow{\chi} \vec{E}$

$\rightarrow$ isotropic material : $\varepsilon_0 \varepsilon_r \vec{E} = \varepsilon_0 \vec{E} \underbrace{(1+\chi)}_{\varepsilon_r}$