Electrodynamics 2 (ELDY2 – Guided electromagnetic waves)

Master program, winter semester 2014-2015, 4+0, exam
Informatic physics, laser technology and electronics, Optics and nanostructures
Lecturer: Prof. Dr. Jiří Čtyroký, DrSc, ctyroky@ufe.cz

Outline:

- Boundary conditions for electromagnetic field at the interfaces between two media. Metal/dielectric interface. Snell's law, Fresnel coefficients. Brewster angle, total reflection, Goos-Hänchen shift.
- Metallic waveguides. Waves guided between two parallel plates. Metallic cylindrical waveguides of a general cross-section. Hertz vectors, TE and TM modes. Critical frequency, propagating and evanescent modes. Lorenz-Lorentz reciprocity theorem, mode orthogonality. Rectangular and circular waveguides. Two-conductor waveguides, TEM mode. Coaxial cable as a waveguide. Consequences of the finite conductivity of metal walls, waveguide loss.
- Waveguide as a transmission line. Characteristic impedance/admittance. Fundamentals of the theory of microwave circuits. Linear N-port, impedance, admittance and scattering matrix. Reciprocal devices, their general properties.
- Cavity resonators. Spectrum of eigenmodes, eigenfrequencies. Rectangular, cylindrical and spherical resonators. Loss due to finite conductivity of walls, quality factor, complex resonant frequency.
- Fresnel diffraction and parabolic equation, Gaussian beam, higher-order (Gauss-Hermite and Gauss-Laguerre) beams. ABCD matrix of an optical element. Transformation of Gaussian beams by optical elements. Open resonators, stability diagram, modes and eigenfrequencies of stable open resonators. Unstable resonators.
- Fundamentals of dielectric waveguides. Planar waveguide, TE and TM modes and their properties. Ray-optic theory of multimode waveguides, concept of phase space, acceptance, guided and leaky modes.
- Fundamentals of electromagnetic theory of optical fibers. LP approximation, rigorous approach and hybrid modes, dispersion equation. Propagation constants and classification of modes.
- Dispersion of optical multimode and single mode waveguides. (Inter)modal dispersion, chromatic dispersion, material and waveguide dispersion, transmission bandwidth. Dispersion management.
- Kerr nonlinearity in fibers, dispersion compensation. Nonlinear Schrödinger equation, soliton propagation.
- Wave propagation in periodic media, Floquet-Bloch modes. Origin of photonic band gap in photonic crystals. Microstructure optical fibers.
- Metal/dielectric interface; surface plasmon (-polariton) as a wave guided by a single interface.

Recommended references:

Lončar, G., Elektrodynamika I, II. skriptum. 1990, Praha: Ediční středisko ČVUT.
Stratton, R.A., Teorie elektromagnetického pole. 1961, Praha: SNTL.
Collin, R.E., Field theory of guided waves. second ed. 1991, New York: IEEE Press.
Saleh, B.E.A. and M.C. Teich, Fundamentals of photonics. 1991, New York: J.Wiley & Sons.
Kogelnik, H. and T. Li, Laser beams and resonators. Applied Optics, 1966. vol. 5, p. 1550–1567.
Unger, H.-G., Planar optical waveguides and fibres. 1977, Oxford: Clarendon Press.
Cancellieri, G., Single-mode optical fibres. 1991, Oxford: Pergamon Press.
Agrawal, G.P, Nonlinear fiber optics, 3rd edition, 2001, Academic Press.
J.D.Joannopoulos, R.D. Meade, J.N. Winn, Photonic crystals: molding the flow of light. 1995, Princeton
S.G.Johnson, J.D.Joannopoulos, Photonic crystals: the road from theory to practice. 2003, Kluwer
H. Raether, Surface Plasmons on Smooth and Rough Surfaces and on Gratings, 1988, Springer.

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