EE231 Introduction to Optics

DESCRIPTION

The course offers a general introduction to optics, covering classical topics such as diffraction, waveguides and resonators, taught in a modern style. Examples and selected lab lessons complement theoretical arguments and concepts introduced during lessons. At the end of the course, the student will be able to understand basic optical systems, and master general concepts of wave propagation that can be applied in a variety of different contexts, from acoustics to microwaves. The topics covered during the lessons are listed below.

Maxwell's equations in isotropic media. Poynting theorem. Definition and physical meaning of the Poynting vector and the energy density of the electromagnetic wave. Complex formalism. Time average of products of sinusoidal functions. Definition of optical intensity. Plane wave solutions of Maxwell's equations. The scalar theory of diffraction. Sommerfield definition of diffraction. Helmholtz equation for the disturbance field. Intensity observable in the scalar approximation. Classical approach to the diffraction problem: definition of propagation and interaction problems. A first example of propagation problem: interference of two non collinear plane waves. Analysis of intensity distribution. Definition of interference fringes and discussion on possible applications. Spherical waves. Paraxial approximation. Interference between a spherical wave and a plane wave. Bessel beam solution of the Helmholtz equations. Field distribution and dispersionless propagation. Discussion and experimental generation of Bessel beams. Elements of linear system theory and Fourier analysis. The propagation problem. General solution through Fourier modal decomposition. Plane-wave propagator. Linear system representation. Evanescent waves and their physical implications. The propagation problem. First formula of Rayleigh-Sommerfield. Huygens principle. Fresnel diffraction integral. Far-Field diffraction formula. Optical resolution limits in the far-field. Double-Slit experiment: analysis with the far-field diffraction integral. Derivation of the paraxial wave equation from Helmholtz equation. Spherical waves and Gaussian beam solutions. Curvature, waist and general properties of Gaussian beams. Direct and Inverse problem of Gaussian beams. Physical explanation of the diffraction of Gaussian beam in terms of dispersion relation. ABCD Law of Gaussian beams. Free space propagation ABCD matrix. The interaction problem: general approach through the transfer function. Exact solution of the interaction with a semi-infinite metallic plane; comparison with the transfer function method; discussion. The thin lens. Transfer function of the thin lens. Application of a thin lens to visualize the far field. Action of a thin lens on a Gaussian Beam. Collimation and Focusing problem. Beam Expander. ABCD matrix of a thin lens. Fresnel diffraction from circular apertures. Fresnel diffraction for opaque discs. Poisson spot. Gratings. General definition. Diffracting orders. Discussion on some possible applications of gratings. Moving gratings. Doppler shift of the input frequency. Application to laser instabilities. Introduction to geometrical optics. Rays and optical paths. Derivation of Snell's law from Fermat principle. Slab waveguides. Definition of guided modes. Geometrical optics analysis of guided modes. Dispersion relation. Symmetric waveguide.

Analysis of dispersion relation of symmetric waveguide. TE and TM modes. Number of modes for a given geometry. Asymetric waveguides: study of the general case. Modal profile of guided modes. The Fabry-Perot interferometer. Reflection and Transmission from multiple rays. Airy's Formulae. Finesse. Interferometer resolving power. Optical cavities. ABCD transfer matrix approach. Stability analysis. Gaussian mode solution of cavities made by spherical mirrors. Phase and amplitude self-consistent equations.

PREREQUISITES

Calculus, Fundamental EM theory, Linear algebra

SEMESTER

Fall

INSTRUCTOR NAME, CONTACT INFORMATION, OFFICE HOURS

Prof. Andrea Fratalocchi

Building 1, Room 4305. I give 100% time availability to my students. If for some reason I am out of my office, please send me an email and we will arrange a meeting.

REFERENCE TEXTS

A. Yariv, Photonics: Optical Electronics in Modern Communications (Oxford University Press, USA, 2006).
J. D. Jackson, Classical Electrodynamics (Wiley, 1998).
M. Born, E. Wolf, Principle of optics: electromagnetic theory of propagation, interference and diffraction of light (Cambridge University Press, Cambridge, 1999).
R. Loudon, The Quantum Theory of Light (Oxford University Press, New York, 2001).
H. Haus, Wave and Fields in Optoelectronics (Prentice Hall, 1989).
J. T. Verdeyen, Laser Electronics (Prentice Hall, 1995).

ATTENDANCE POLICY required, students that miss more than 10% of the course with no written justification (email) will not be admitted at the exam

HONOR CODE

> In accordance with the University policy and professional standards, the highest levels of academic integrity are expected in this class. The code of student conduct is strictly enforced. Academic dishonesty will result in reductions in grades and/or expulsions from this class and/or the University.

GRADING POLICY:

The exam is graded from two written exams (midterm and final) and an oral discussion, with modality described as follows. Each written exam is composed by oral questions and exercises. A student that gets A in both written exams does not need to perform an oral and the final grade is A. A student that gets A- at the written exams has an optional oral discussion, which if taken will form 25% of the final grade. If the oral option is not taken, the final grade is A-. Students with average grade below A- at the written have a compulsory oral discussion, which will form 50% of the final grade. Students that get a failing grade both at the midterm and final will not be admitted at the oral and get a failing grade calculated from the average grade of the written exams.

HOMEWORK: after every lesson (not graded, compulsory). Homework exercises are collected at every lesson. Students that do not execute or deliver the homework will not be admitted at the exam. Students that well execute the homework will have a grade bonus at the oral exam.

CLASS MATERIALS, HANDOUTS, POSTING

Updated slides are found at my group website www.primalight.org→teaching <u>The slides are not reference texts, the texts are listed above.</u>

COMMUNICATION INSTRUCTIONS

Website www.primalight.org and email

CLASS SCHEDULE at www.primalight.org → teaching