UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Interazione Luce Materia

2122-3-E3002Q029

Aims

The aim of the course is to describe the different processes through which light interacts with atoms, molecules and bulck materials. Starting from the phenomena that can be described simply on the basis of Maxwell's equations, we will then move on to the illustration of those that require a more sophisticated approach up to the photophysics of vision.

Contents

1. WAVE-PARTICLE DUALITY (hints) and MATHEMATICAL REPRESENTATION OF WAVES: Real representation and complex representation of waves; Phase and phase velocity of a wave; Scalar and vector waves; Polarized plane waves.

2. ELECTROMAGNETIC WAVES: Maxwell's equations (review); Wave equation: propagation of electromagnetic waves in vacuum and in materials; Complex refractive index and complex dielectric function; Dispersion and attenuation of electromagnetic waves in materials; Lorentz and Drude models.

3. TRANSMISSION AND REFLECTION: Transmission of electromagnetic waves; Absorption coefficient and Lambert-Beer law; Reflectivity at normal incidence; Transmittance, absorbance and reflectance spectra at normal incidence; Refraction and reflection of linearly polarized light at oblique incidence; Fresnel equations; Brewster's law and polarization of light by reflection; Color produced by refraction.

4. OPTICAL ANISOTROPY: Bravais lattice definition (outline); Dielectric tensor of anisotropic media; Propagation of electromagnetic waves in anisotropic media; Birefringence; Waveplates; Dichroic polarizers.

5. INTERFERENCE AND DIFFRACTION. Fraunhofer diffraction and limit of resolution. Pure interference (thin films). Diffraction gratings.

6. DIFFUSION OF LIGHT: Rayleigh scattering; Raman scattering; Mie scattering; Color produced by diffusion.

7. LIGHT-ATOM AND LIGHT-MOLECULES INTERACTION: Introduction to optical spectroscopy; Hund's rules; Atomic transitions and selection rules; Light produced by gas excitation (comparison with light produced by black body emission); Outline of laser physics; Molecular transitions; Color of organic molecules; Beyond the single atom / molecule: the color of metals, insulators and semiconductors.

8. VISION: Photophysics of the vision process; Photopic and scotopic vision; Colorimetry: measurement and production of colors.

Detailed program

1) Wave-particle duality. (Notes from Prof. Tavazzi)

2) Mathematical representation of the waves. (Notes from Prof. Tavazzi)

3) Maxwell's equations: meaning and solutions. (Notes by prof.ssa Tavazzi + http://onlinelibrary.wiley.com/doi/10.1002/9780470060193.app2/pdf for conventions + a textbook of electromagntis and / or http://onlinelibrary.wiley.com/doi/10.1002/9780470060193.app3/pdf for the resolution procedure).

4) Lambert-Beer law. (Notes from Prof. Tavazzi)

5) Reflectivity at normal incidence. (Prof. Tavazzi notes + a textbook of electromagntis for boundary conditions)

6) Reflectance and transmittance (hints). (Notes from Prof. Tavazzi)

7) Reflectivity at oblique incidence. (Prof. Tavazzi notes + a textbook of electromagntis for boundary conditions)

8) Anisotropic media. (Notes from Prof. Tavazzi)

9) Lorentz and Drude models. (http://scitation.aip.org/content/aapt/journal/ajp/40/10/10.1119/1.1986862)

10) Photometry. (http://hyperphysics.phy-astr.gsu.edu/hbase/vision/lumpow.html#c1, http://hyperphysics.phy-astr.gsu.edu/hbase/vision/radphocon.html#c1, http://hyperphysics.phy-astr.gsu.edu/hbase/vision/photom.html#c1, http://hyperphysics.phy-astr.gsu.edu/hbase/vision/bright.html#c2)

11) Colorimetry. (Both Sears and Nassau are suitable. Perhaps it is easier to study it on the former)

12) Color by refraction / dispersion. (Nassau chap. 10 up to page 226, but not Appendix F. Additional details on: http://hyperphysics.phy-astr.gsu.edu/hbase/atmos/rainbowcon.html#c1)

13) Color by interference and diffraction. (Sears for the basic theory + http://hep.fi.infn.it/FOC/didattica/beniculturali/fisica2/lez24.pdf. Nassau chap. 12, plus the paragraph on interference in a thin film of appendix F, but not the paragraph "Diffraction from a layer grating" of the same appendix)

14) Diffusion of light. (Nassau chapter 11 up to page 241 + http://www2.mater.unimib.it/utenti/meinardi/Integration_Raman.doc)

15) Elements of atomic physics. (Nassau appendix C + Chapter 3 up to page 56 + http://hyperphysics.phy-astr.gsu.edu/hbase/atomic/hund.html and http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/hydfin.html#c2 for Hund's rules + http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/schr.html#c3 for energy calculation)

16) Color in organic molecules. (https://www2.chemistry.msu.edu/faculty/reusch/virttxtjml/intro3.htm#strc8c only chapter orbitals + http://www2.mater.unimib.it/utenti/meinardi/Integration_Organiche.docx + Nassau chapter 6 up to Polyene Colorants)

17) Vision. (Nassau chap. 14 up to Human color vision + http://www.chemistry.wustl.edu/~edudev/LabTutorials/Vision/Vision.html + http://www.sciencemag.org/content/254/5030/ 412.full.pdf)

18) Emission of black body (hints). (Nassau chapter 2 up to page 45 + appendix B for Laws of Stefan and Wien + http://www.lucevirtuale.net/percorsi/b1/corpo_nero.html)

19) Color in metals and semiconductors. (Nassau chapter 8 up to LEDS and semiconductor lasers (excluded) + appendix E)

20) Laser: general theory plus operation of a specific laser among those discussed at the student's choice. (http://www2.mater.unimib.it/utenti/meinardi/Integration_Laser.doc)

Prerequisites

It is assumed that the students already have a good knoweldge of the main contents of the courses of Physics 2, Mathematics 1 and 2, and Geometric Optics. In particular, the following notions are taken for known and are absolutely essential:

1) Calculation of the modulus of a complex number (regardless of its representation)

2) Calculation of the scalar and vector product

3) Definition of radiant

4) Definition of incident plane

5) Laws of reflection

6) Definition of momentum

7) Definition of angular momentum

8) Definition of limit angle

9) Waves: definition of period, frequency, amplitude and wavelength

10) Reading of graphs in linear, semi-logarithmic and double logarithmic scale.

11) Definition of polarization p and s.

Teaching form

Lectures (in Italian). Textbooks and additional materials may be in both Italian and English.

Textbook and teaching resource

F.W. Sears, Ottica, Ed. CEA

K. Nassau, “The Physics and chemistry of colors”, J. Wiley & Sons, Inc.

Prof.ssa Tavazzi's notes (can be downloaded here: https://drive.google.com/drive/folders/1vVCSgW9Vbk89tuiHYTEJ4a5P1zvcuRm0?usp=sharing. Please note that these notes can complement but not replace textbooks.

Material provided by the teacher (see syllabus).

Semester

First semester

Assessment method

Written test and oral exam. There are no ongoing tests.

The written test does not have any score but simply an admission or non-admission judgment to the oral exam. It consists of simple exercises, and is aimed at verifying the student's ability to apply the main results of the studied theory to simple real cases.

The oral exam, with a grade expressed out of 30, consists of an interview on the topics explained during the lectures and aims to verify:

1) the property of language

2) knowledge of the theories addressed in the course

3) the level of understanding of the theories addressed in the course

It is possible, at the request of the student, to take the exam in English.

Office hours

Every day by appointment.