Optical Materials
Fall 2016; Course No. 14:635:433
Department of Materials Science and Engineering
Rutgers, The State University of New Jersey

Syllabus

Time: 3.20 pm - 4.40 pm, Tues. & Thur.
Location: SEC 204, Busch Campus
Instructor: Deirdre O'Carroll, CCR 218
Office Hours: Tue. 1 - 2 pm; Thur. 1 - 2 pm
Contact: ocarroll@rutgers.edu

Description: This course will describe the properties of important passive and active optical materials including glasses, crystals, polymers, semiconductors and metals. The first part of the course will introduce fundamental concepts behind light-matter interactions such as dielectric constant, refractive index, optical transmission, refraction and reflection, macroscale and mesoscale optical interactions, and the materials chemistry and physics necessary to be able to interpret the optical properties of materials. Next, important experimental measurement and theoretical simulation approaches will be highlighted. In the second part of the course the unique optical characteristics, properties and applications associated with various types of optical materials will be covered. Materials of interest will be crystalline, semiconducting, and glassy solids including passive optical polymers, oxide and fluoride glasses, inorganic semiconductor like Si, Ge and GaAs, organic optically-active semiconductors, non-linear optical materials and new optical materials such as metamaterials, optical composites and quantum optical materials. For the various optical material types, there will be explanations of composition, fabrication and applications of the materials such as optical fiber communications, microscopy, display and lighting and optical sensing.

Objective: The primary objective of the course is to provide an understanding of the origins and uses of the optical properties of materials. The student will be exposed to a quantitative interpretation of the fundamentals of the interaction of light with passive and active optical materials as well as general information on the applications of optical materials in optical engineering. A major objective of the course is for students to learn how to apply course knowledge to solve real-world problems in a variety of optical engineering applications. The students should be prepared by the end of the course to work in industries employing enabling optical technologies or to continue in graduate school in more advanced optical materials research and development.

Prerequisites: none

Reference Texts (not required):
- Optical Properties of Solids by Mark Fox, Oxford University Press, New York 2001.
- Photonics by Amnon Yariv & Pochi Yeh, Oxford University Press, 6th Edition, New York, 2007.
- Introduction to Modern Optics by Grant R. Fowles, Dover Publications, 2nd Edition, New York 1989.
- Materials Chemistry by Bradley D. Fahlman, Springer, 2nd Edition, New York, 2011.

Course Materials: The instructor will use both the blackboard and the projector to convey class notes, slides, diagrams, equations, etc. Students are expected to write down notes, diagrams, equations and orally-taught concepts in a personal class notepad. Class lecture slides (including relevant equations and diagrams), supplementary reading materials and homework questions will be posted on Sakai in conjunction with syllabus topics. The course instructor retains copyright of all lecture slides, course notes, summary sheets and homework questions disseminated during classes or posted on Sakai and *these materials are not to be distributed to persons not registered for this course or to other media or websites without written permission from the course instructor*.

Topics Covered:

Introduction to Light-Matter Interactions:
- Introduction; passive & active optical materials; dielectric constant & refractive index
- Electromagnetic radiation; Maxwell's Equations; quantum nature of light
- Origin of the dielectric constant: frequency dependence; Lorentz Model
- Dispersive optical constants
- Absorption, transmission, reflection (Fresnel Equations), refraction, diffraction, emission, scattering (phonons, elastic, Raman, Brillouin), polarization
- Measurement and simulation of the optical properties of materials

Passive Optical Materials:
- *Glasses:* silicates, fluoride, chalcogenides, origin of color in glasses
- *Polymers:* optical constants, specialty optical applications, polarization
- *Crystals:* polarization, birefringence, waveplates, liquid crystals
- *Passive optical components*: lenses; optical coatings; mirrors; gratings, photonic bandgap materials
- *Optical waveguides*: thin films (slab); optical fibers; mode equations and profiles, mode cutoff
- *Metals:* physical origin of the dielectric constant, reflectance, surface plasmons

Active Optical Materials:
- *Semiconductors*: interband absorption; direct, indirect bandgap; Si, III-V; II-V
- *Semiconductors*: nanoscale phenomena, excitons, quantum confinement, quantum optics
- *Semiconductors:* organic semiconductors; small molecules; conjugated polymers
- *Applications of active semiconductor optical materials:* photodetectors, amplifiers (lasers), lighting, displays.
- *Nonlinear optical materials:* Nonlinear optical properties; gain materials; upconversion; harmonic generation, electrooptic materials
- *Plasmonics:* localized and propagating surface plasmons
- *Metamaterials:* optical frequency magnetic permeability

Important Dates, Exams, Homework and Grading:

Assessment Type	Date	Information	Duration	% of Total Course Grade
Homework	Exact due date for each homework assignment will be specified upon assignment.	5 homework assignments will be given.	Throughout the course.	30 %
Exam 1	Oct. 11th (Tuesday)	Will cover all preceding lectures.	60 min.	15 %
Exam 2	Nov. 15th (Tuesday)	Will cover all lectures not covered by Exam 1.	60 min.	15 %
Final Exam	Dec. 16th (8 am - 11 am; Friday)	Will cover all lectures given during the entire semester.	180 mins.	35 %
Attendance	All semester	Attendance will be taken in each class and the attendance grade will be calculated based on your percentage attendance.	-	5 %

Tentative Class Schedule:

Sept. 6th	Introduction; syllabus, prior knowledge quiz, passive and active optical materials; dielectric constant and refractive index
Sept. 8th	Electromagnetic radiation; Maxwell's equations; quantum nature of light **Homework 1 assigned.**
Sept. 13th	Origin of the dielectric constant: frequency dependence; Lorentz Model
Sept. 15th	Dispersive optical constants; absorption, transmission
Sept. 20th	Reflection (Fresnel Equations), refraction, diffraction **Homework 1 due. Homework 2 assigned.**
Sept. 22nd	Emission, scattering, polarization
Sept. 27th	Measurement and simulation of the optical properties of materials
Sept. 29th	Optical properties of glasses
Oct. 4th	Optical properties of polymers **Homework 2 due.**
Oct. 6th	Review class
Oct. 11th	**Exam 1: Covers all lectures to date.**
Oct. 13th	Optical properties of crystals **Homework 3 assigned.**
Oct. 18th	Optical properties of metals
Oct. 20th	Applications of passive optical materials
Oct. 25th	Optical waveguides **Homework 3 due. Homework 4 assigned.**

Oct. 27th	Optical properties of inorganic semiconductors
Nov. 1st	Optical properties of organic semiconductors
Nov. 3rd	Semiconductors: Nanoscale phenomena
Nov. 8th	Applications of active semiconductor optical materials **Homework 4 due.**
Nov. 10th	Review class
Nov. 15th	**Exam 2: Covers all lectures to date not covered by Exam 1.**
Nov. 17th	Optical properties of nonlinear optical materials **Homework 5 assigned.**
Nov. 22nd	Plasmonics
Nov. 24th	**Thanksgiving recess – no class**
Nov. 29th	**MRS Fall – no class**
Dec. 1st	**MRS Fall – no class**
Dec. 6th	Metamaterials and metasurfaces
Dec. 8th	Novel applications **Homework 5 due.**
Dec. 13th	Review class
Dec. 16th	**Final Exam: Covers all lectures. (8 am to 11 am)**

University and School of Engineering Academic Policies and Student Support

Academic Integrity

115 College Avenue, New Brunswick | (848) 932-9414 |
academicintegrity.rutgers.edu
Academic integrity is essential to the success of the University's educational and research missions, and violations of academic integrity constitute serious offenses against the entire academic community. The principles of academic integrity require that a student:

- Properly acknowledge and cite all use of the ideas, results, or words of others.
- Properly acknowledge all contributors to a given piece of work.
- Make sure that all work submitted as his or her own in a course or other academic activity is produced without the aid of impermissible materials or impermissible collaboration.
- Obtain all data or results by ethical means and report them accurately without suppressing any results inconsistent with his or her interpretation or conclusions.
- Treat all other students in an ethical manner, respecting their integrity and right to pursue their educational goals without interference. This requires that a student neither facilitate academic dishonesty by others nor obstruct their academic progress.
- Uphold the canons of the ethical or professional code of the profession for which he or she is preparing.

Rutgers University is committed to fostering an intellectual and ethical environment based on the principles of academic integrity. Every member of the University community bears a responsibility for ensuring that the highest standards of academic integrity are upheld.

Student Advising

General Advising: Office of Academic Services
Engineering B100, Busch Campus | (848) 445-2212 | soe.rutgers.edu/oas
Undergraduate advisors and deans are available to you at the School of Engineering to assist you with inquiries related to course planning, academic policies, professional development, scholastic standing, degree progress, withdrawal options, and more. Please visit soe.rutgers.edu/oas/advising for work-in and advising hours,

Advising in Major: Engineering Departments
Busch Campus | soe.rutgers.edu/deptadvising
The Undergraduate Directors in the engineering, math, and science departments are available to assist students in the areas of scheduling of major courses, special permission numbers, BS/MS advising, and other areas related to the engineering major course requirements. See the webpage above for more locations and more information.

Absences Verification

Dean of Students office | Hours & Locations: deanofstudents.rutgers.edu
Any student who needs verification of an absence (illness, conference, corporate or graduate school interview, etc.) should contact the Dean of Students office. The Dean of Students will need documentation in order to verify your absence and will then email your professor that your absence has been substantiated. If you know in advance that you will be absent from a class, it is also a good idea to submit the Self-Reporting Absence Application (sims.rutgers.edu/ssra). In both situations this does not necessarily imply that a student will be excused from the class, any assignments that were due or attendance that may be required.

Course or Semester Withdrawal

Online or Visit Engineering B100 | soe.rutgers.edu/add-drop
- The last day to drop a course without a "W" via WEBREG is within the **1st week** of classes.
- The last day to drop a class via WebReg with a 'W' grade is the **8th week**.
- With Dean's permission from Engineering B100, students may drop SoE courses (14:xxx:xxx) before the **10th week** with a 'W' grade.
- Students are not allowed to drop individual class after the **10th week**.
- The last day to withdraw from ALL classes with all 'W' grades (semester withdrawal) is the end of the **12th week**.

University Policy on Exam Scheduling and Conflicts

Office of Registrar | nbregistrar.rutgers.edu/facstaff/examrules.htm
The University has a strict policy on not allowing final exams to be scheduled during the last two weeks of the class period. There are also similar policies regarding the reading days and a detailed guideline on how to handle exam conflicts. For more information, please visit the Registrar's page on exam policy above.

Academic Coaching, Tutoring, Learning Support

Rutgers Learning Centers | (848) 445-0986 | lrc.rutgers.edu
Academic coaching is a comprehensive service for students who want to improve their academic and self-management skills, such as time management, organization and

study skills. The Rutgers Learning Centers offer this support to help students achieve their academic goals along with self-advocacy and independent, life-long learning. To schedule an appointment, you may visit their website or call.

Student-Wellness Services

Counseling, ADAP & Psychiatric Services (CAPS)
17 Senior Street, New Brunswick | (848) 932-7884 | rhscaps.rutgers.edu
CAPS is a University mental health support service that includes counseling, alcohol and other drug assistance, and psychiatric services staffed by a team of professional within Rutgers Health services to support students' efforts to succeed at Rutgers University. CAPS offers a variety of services that include: individual therapy, group therapy and workshops, crisis intervention, referral to specialists in the community and consultation and collaboration with campus partners.

Violence Prevention & Victim Assistance (VPVA)
3 Bartlett Street, New Brunswick | (848) 932-1181 | www.vpva.rutgers.edu
The Office for Violence Prevention and Victim Assistance provides confidential crisis intervention, counseling and advocacy for victims of sexual and relationship violence and stalking to students, staff and faculty. To speak with someone immediately, call 848-932-1181.

Disability Services
Lucy Stone Hall, Suite A145, Livingston Campus | (**848) 445-6800 | ods.rutgers.edu**
Rutgers University welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation:ods.rutgers.edu/students/documentation-guidelines. If the documentation supports your request for reasonable accommodations, your campus's disability services office will provide you with a Letter of Accommodations. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. To begin this process, please complete the Registration form on the ODS web site at: ods.rutgers.edu/students/registration-form.

Scarlet Listeners
(732) 247-5555 | scarletlisteners.com
Free and confidential peer counseling and referral hotline, providing a comforting and supportive safe space.

Download the Just-In-Case App: http://codu.co/cee05e
Access helpful mental health information and resources for yourself or a friend in a mental health crisis on your smartphone or tablet and easily contact CAPS or RUPD.