CREOL, The College of Optics and Photonics

OSE 5312: Light Matter Interaction
CREOL, The College of Optics and Photonics
Credit Hours: 3
Term: Spring 2024

Syllabus

Time:	Tue-Thu, 10:30-11:45am, and Jan 9th-April 30th, 2024
Location:	CREOL rm 102
Prerequisites:	Graduate standing or consent of instructor
Course Description:	Microscopic theory of absorption, dispersion, and refraction of materials; classical and quantum mechanical description of optical properties.
Instructor:	Prof. Romain Gaume
Email/Contact Info:	gaume@ucf.edu
Office Hours and Location:	Tue 12-1pm, CREOL office A339
Course Modality:	P, V
GTAs:	N/A

Course Overview

This course discusses the interaction of light with matter. We will find that many important optical properties can be described quite accurately using surprisingly simple models. Initially, we will model atoms as classical dipole oscillators ("electrons on springs"). We will use the calculated behavior of these model atoms together with Maxwell's equations to obtain expressions for the frequency dependent refractive index, absorption, and susceptibility. Using this theory, we will be able to understand the optical properties of gases, liquids and solids, including metals, semiconductors and dielectrics. To improve on our model descriptions, we will discuss the foundations of quantum mechanics and derive a quantum mechanical description of the refractive index. We will include the interaction of light with oscillations of atoms (molecular vibrations and rotations, phonons) and consider how quantum mechanics affects molecular absorption spectra.

List of topics covered:

Maxwell's Equations and the Dielectric Function: free charges, meaning of susceptibility and polarization response, bound electron polarization and magnetization, causality & Kramers-Kronig relations, Optical Properties of Solids, Liquids and Gases: molecules, liquids, metals, insulators, semiconductors, Classical Treatment of Light-Matter Interaction: Lorentz oscillator, Drude model, Debye model, calculation of susceptibility and complex refractive index, Sellmeier equations and Abbe number, electronic transitions in atoms, anharmonic classical oscillator model, second order effects, third order effects, molecular rotational/vibrational transitions in molecules, dipole-active and Raman-active modes, phonons in solids, acoustic modes, optical modes, Quantum-mechanical description of Light-Matter Interaction: operators, Eigenfunctions, orthonormal complete sets, Dirac notation, wavefunctions, observables, commutation, ensemble averages, energy Eigenfunctions, time

independent Schrödinger equation, infinite and finite wells, barriers, time dependent Schrödinger equation, time dependent perturbation theory, Fermi Golden Rule, expectation value of Polarization, susceptibility, oscillator strength , dopants / impurities in dielectric hosts, Kronig-Penney model and Energy bands, Bandgaps, Excitons, impurities (n- and p-type), blackbody radiation, Einstein coefficients, Thermal distributions (Bose-Einstein, Fermi-Dirac, Maxwell-Boltzmann).

Student Learning Outcomes and Measures

Students will be able to identify materials based on reflection, transmission, absorption spectra, predict optical properties based on dopant concentrations and resonances, predict refractive index spectra based on absorption spectra, and understand the role of quantum mechanics in optical properties.

Course Materials:

Course notes will be provided on Webcourses (pptx or pdf).

Optional textbooks:

Optical Properties of Solids	M. Fox (Oxford University Press)
Quantum Mechanics for Scientists and Engineers	D. A. B. Miller (Cambridge)
Optical Materials	J. Simmons and K. S. Potter (Academic Press)
Introduction to Solid State Physics	C. Kittel (Wiley)
Optical Electronics in Modern Communications	A. Yariv (Oxford)

Weekly Schedule

The following dates are tentative, and updates will be provided based on course progression.

Day	Date	Subjects covered	Description	Notes	Fox	Miller
T	9-Jan	Introduction - broad overview of topics to be covered		1	1	
Th	11-Jan	Review of Maxwell's equations	continuum	2	2	
T	16-Jan	Wave propagation in dispersive media	continuum	3	2	
Th	18-Jan	Kramers-Kronig relations	continuum	4	2	
T	23-Jan	Dielectrics - the Lorentz model (1)	oscillator (classical)	5	2	
Th	25-Jan	Dielectrics - the Lorentz model (2)	oscillator (classical)	5	2	
T	30-Jan	Metals and doped semiconductors - Drude model	oscillator (classical)	8	7	
Th	1-Feb	More on Lorentz model, anharmonic oscillator and pathways to NLO	oscillator (classical)	15	11	
T	6-Feb	Nonlinear optics; frequency mixing: sum and difference frequency generation	oscillator (classical)	15	11	
Th	8-Feb	Nonlinear optics; frequency mixing: sum and difference frequency generation	oscillator (classical)	15	11	
T	13-Feb	QM1 - Introduction to Schrödinger equation, states of an infinite well	quantum	-		2
Th	15-Feb	QM2 - States of a finite well	quantum	-		2
T	20-Feb	QM3 - Time dependence, expectation values, orthonormal complete sets	quantum	-		3
Th	22-Feb	QM4 - Example basis sets, Harmonic oscillator, Hydrogen atom	quantum	-		3, 10
T	27-Feb	**Midterm Exam**				
Th	29-Feb	QM5 - Time dependent perturbation	quantum	-		7
T	5-Mar	QM6 - From time dependent amplitudes to absorption coefficient	quantum	-	B	7
Th	7-Mar	QM7 - From time dependent amplitudes to susceptibility	quantum	-	B	7
T	12-Mar	Molecular vibrations, quantum rotor, vibration - rotation spectra	oscillator (Q & class)	10,7		
Th	14-Mar	Classical and quantum description of vibrations in molecules I	oscillator (classical)	6,10		
T	19-Mar	No Class (Spring Break)				
Th	21-Mar	No Class (Spring Break)				
T	26-Mar	Classical and quantum description of vibrations in molecules II	oscillator (classical)	6,10		
Th	28-Mar	Vibrations in solids I; phonon dispersion in linear chains of atoms	oscillator (classical)	10	10	
T	2-Apr	Vibrations in solids II; reciprocal space, phonon dispersion in real materials		10	10	
Th	4-Apr	Vibrations in solids III; reciprocal space, phonon dispersion in real materials		10	10	
T	9-Apr	Optical properties of semiconductors - Kronig-Penney Model and Bandgaps	QM & band structure	11	3, C	8
Th	11-Apr	Optical properties of semiconductors - Band structure	QM & band structure	11	3, C	8
T	16-Apr	Optical properties of semiconductors - Interband transitions	QM & band structure	11	3, C	8
Th	18-Apr	Optical properties of semiconductors - excitons, impurities, FCA	QM & band structure	11	4	8
T	23-Apr	No Class				
Th	25-Apr	No Class				
T	**30-Apr**	**FINAL EXAM: 10:00am-12:50 am Room 102**				

Deadlines, Holidays, and Significant Semester Events:
Please refer to the UCF Academic Calendar and the UCF Exam Schedule for more information such as Exam Dates, Add/Drop, Withdrawal, and Grade Forgiveness Deadlines. Important dates include university holidays or closures, drop/withdrawal deadlines, exam dates, assignment deadlines, or other dates in the UCF Academic Calendar that pertain to your course.

Email: Feel free to email me regarding any question or concern about the class or to request a meeting.

Webcourses: Webcourses will be used to communicate class notes (pdf files), assignments, grades or general messages to the class. You will also upload your assignments on this platform.

Laptop/Tablet Usage: If you like, you are welcome to take notes with your personal laptop or tablet during the lectures.

Course Grading:
The semester's grade will be obtained from the following assessments and weights:

Assignments	Grade Weighting
Homework (6)	60%
Midterm Exam (1)	20%
Final Exam (1)	20%
Total	**100%**

Grade		Description
94-100 90-93	A A-	Excellent, has a strong understanding of all concepts and is able to apply the concepts in all and novel situations. Has full mastery of the content of the course.
87-89 84-86 80-83	B+ B B-	Good, has a strong understanding of most or all of the concepts and is able to apply them to stated and defined situations.
77-79 74-76 70-73	C+ C C-	Average, has a basic understanding of the major concepts of the course and is able to apply to basic situations.
67-69 64-66 60-63	D+ D D-	Below average, has a basic understanding of only the simple concepts and is able to apply to only a limited number of the most basic situations.
0 - 59	F	Demonstrates no understanding of the course content.

Grades of "Incomplete":
The current University policy concerning incomplete grades will be followed in this course. Incomplete grades are given only in situations where unexpected emergencies prevent a student from completing the course and the remaining work can be completed the next semester. Your instructor is the final authority on whether you qualify for an incomplete. Incomplete work must be finished by the end of the subsequent semester or the "I" will automatically be recorded as an "F" on your transcript.

Late Work Policy:
Homework posted in late will be assessed a penalty: a half-letter grade if it is one day late, or a full-letter grade for 2-7 days late. Homework will not be accepted if overdue by more than seven days or after solutions are posted. Makeup exams will only be offered with prior permission from instructor.

Make Up Policy: If an emergency arises and a student cannot submit assigned work on or before the scheduled due date or cannot take an exam on the scheduled date, the student **must** give notification to the instructor **no less than 24 hours before** the scheduled date and **no more than 48 hours after the** scheduled date.

Grade Objections:
All objections to grades should be made **in writing within one week** of the work in question.
Objections made after this period has elapsed will **not** be considered – NO EXCEPTIONS.

Financial Aid and Attendance:
All faculty members are required to document students' academic activity at the beginning of each course. In order to document that you began this course, I will request that you complete a non-graded exercise by the end of the first week of classes, or as soon as possible after adding the course, but no later than **January 17th**. Failure to do so will result in a delay in the disbursement of your financial aid.

Grade Dissemination
Graded tests and materials in this course will be returned individually only by request. You can access your scores at any time using the Grade Book function of Webcourses. Please, note that scores returned mid-semester are unofficial grades.

Academic Integrity
Students should familiarize themselves with UCF's Rules of Conduct at <https://scai.sdes.ucf.edu/student-rules-of-conduct/>. According to Section 1, "Academic Misconduct," students are prohibited from engaging in:

1. Unauthorized assistance: Using or attempting to use unauthorized materials, information or study aids in any academic exercise unless specifically authorized by the instructor of record. The unauthorized possession of examination or course-related material also constitutes cheating.
2. Communication to another through written, visual, electronic, or oral means: The presentation of material which has not been studied or learned, but rather was obtained through someone else's efforts and used as part of an examination, course assignment, or project.
3. Commercial Use of Academic Material: Selling of course material to another person, student, and/or uploading course material to a third-party vendor without authorization or without the express written permission of the university and the instructor. Course materials include but are not limited to class notes, Instructor's PowerPoints, course syllabi, tests, quizzes, labs, instruction sheets, homework, study guides, handouts, etc.
4. Falsifying or misrepresenting the student's own academic work.
5. Plagiarism: Using or appropriating another's work without any indication of the source, thereby attempting to convey the impression that such work is the student's own.
6. Multiple Submissions: Submitting the same academic work for credit more than once without the express written permission of the instructor.
7. Helping another violate academic behavior standards.
8. Soliciting assistance with academic coursework and/or degree requirements.

Responses to Academic Dishonesty, Plagiarism, or Cheating
Students should familiarize themselves with the procedures for academic misconduct in UCF's student handbook, *The Golden Rule* <https://goldenrule.sdes.ucf.edu/>. UCF faculty members have a responsibility for students' education and the value of a UCF degree, and so seek to prevent unethical behavior and respond to academic misconduct when necessary. Penalties for violating rules, policies, and instructions within this course can range from a zero on the exercise to an "F" letter grade in the course. In addition, an Academic Misconduct report could be filed with the Office of Student Conduct, which could lead to disciplinary warning, disciplinary probation, or deferred suspension or separation from the University through suspension, dismissal, or expulsion with the addition of a "Z" designation on one's transcript.

Being found in violation of academic conduct standards could result in a student having to disclose such behavior on a graduate school application, being removed from a leadership position within a student organization, the recipient of scholarships, participation in University activities such as study abroad, internships, etc.

Let's avoid all of this by demonstrating values of honesty, trust, and integrity. No grade is worth compromising your integrity and moving your moral compass. Stay true to doing the right thing: take the zero, not a shortcut.

Professionalism Policy:
Per university policy and classroom etiquette, mobile phones, iPods, *etc*. **must be silenced** during lectures. Those not heeding this rule will be asked to leave the classroom immediately so as to not disrupt the learning environment. Please, arrive on time for all class meetings. Students who habitually disturb the class by talking, arriving late, *etc*., and have been warned may suffer a reduction in their final class grade.

Unauthorized Use of Websites and Internet Resources
There are many websites claiming to offer study aids to students, but in using such websites, students could find themselves in violation of academic conduct guidelines. These websites include (but are not limited to) Quizlet, Course Hero, Chegg Study, and Clutch Prep. UCF does not endorse the use of these products in an unethical manner, which could lead to a violation of our University's Rules of Conduct.

They encourage students to upload course materials, such as test questions, individual assignments, and examples of graded material. Such materials are the intellectual property of instructors, the university, or publishers and may not be distributed without prior authorization. Students who engage in such activity could be found in violation of academic conduct standards and could face course and/or University penalties. Please let me know if you are uncertain about the use of a website so I can determine its legitimacy.

Unauthorized Distribution of Class Notes
Third parties may attempt to connect with you to sell your notes and other course information from this class. Distributing course materials to a third party without my authorization is a violation of our University's Rules of Conduct. Please be aware that such class materials that may have already been given to such third parties may contain errors, which could affect your performance or grade.

Recommendations for success in this course include coming to class on a routine basis, visiting me during my office hours, connecting with the Teaching Assistant (TA), and making use of the Student Academic Resource Center (SARC), the University Writing Center (UWC), the Math Lab, etc. If a third party should

contact you regarding such an offer, I would appreciate your bringing this to my attention. We all play a part in creating a course climate of integrity.

In-Class Recording
Students may, without prior notice, record video or audio of a class lecture for a class in which the student is enrolled ***for their own personal educational use***. A class lecture is defined as a formal or methodical oral presentation as part of a university course intended to present information or teach enrolled students about a particular subject.

Recording class activities other than class lectures, including but not limited to class discussion, academic exercises involving student participation, test or examination administrations, private conversations between students in the class or between a student and the faculty member, and invited guest speakers is prohibited.

Recordings may not be used as a substitute for class participation and class attendance and may not be published or shared without the written consent of the faculty member. Failure to adhere to these requirements may constitute a violation of the University's Student Code of Conduct as described in the Golden Rule.

Course Accessibility Statement
The University of Central Florida is committed to providing access and inclusion for all persons with disabilities. Students with disabilities who need access to course content due to course design limitations should contact the professor as soon as possible. Students should also connect with Student Accessibility Services (SAS) http://sas.sdes.ucf.edu/ (Ferrell Commons 185, sas@ucf.edu, phone 407-823-2371).

For students connected with SAS, a Course Accessibility Letter may be created and sent to professors, which informs faculty of potential course access and accommodations that might be necessary and reasonable. Determining reasonable access and accommodations requires consideration of the course design, course learning objectives and the individual academic and course barriers experienced by the student. Further conversation with SAS, faculty and the student may be warranted to ensure an accessible course experience.

Deployed Active-Duty Military Students
If you are a deployed active-duty military student and feel that you may need a special accommodation due to that unique status, please contact your instructor to discuss your circumstances.

Campus Safety Statement
Emergencies on campus are rare, but if one should arise during class, everyone needs to work together. Students should be aware of their surroundings and familiar with some basic safety and security concepts.

- In case of an emergency, dial 911 for assistance.
- Every UCF classroom contains an emergency procedure guide posted on a wall near the door. Students should make a note of the guide's physical location and review the online version at https://centralflorida-prod.modolabs.net/student/safety/index.
- Students should know the evacuation routes from each of their classrooms and have a plan for finding safety in case of an emergency.

- If there is a medical emergency during class, students may need to access a first-aid kit or AED (Automated External Defibrillator). To learn where those are located, see https://ehs.ucf.edu/automated-external-defibrillator-aed-locations.
- To stay informed about emergency situations, students can sign up to receive UCF text alerts by going to https://my.ucf.edu and logging in. Click on "Student Self Service" located on the left side of the screen in the toolbar, scroll down to the blue "Personal Information" heading on the Student Center screen, click on "UCF Alert", fill out the information, including e-mail address, cell phone number, and cell phone provider, click "Apply" to save the changes, and then click "OK."
- Students with special needs related to emergency situations should speak with their instructors outside of class.
- To learn about how to manage an active-shooter situation on campus or elsewhere, consider viewing this video https://youtu.be/NIKYajEx4pk.