UNIVERSITY OF CENTRAL FLORIDA

OSE 6334C - Nonlinear Optics

Section: 0001

Optics and Photonics

Course Information

Term: Spring 2025
Class Meeting Days: MW
Class Meeting Time: 01:30PM - 02:45PM
Class Meeting Location: CROL 0102
Modality: P
Credit Hours: 3.00

Instructor Information

Konstantin Vodopyanov
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Office Hours:
By arrangement
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Course Description

OSE 6334C OPT-OPT 3(2.5,0.5)Nonlinear Optics: PR: Graduate standing and OSE 6111 or C.I. Maxwell's equations in nonlinear media, frequency conversion techniques (SHG, SFG, OPO), stimulated scattering, phase conjugation, wave-guided optics, nonlinear crystals. Spring.

This course studies the interaction of sufficiently intense light with an optically transparent substance when the interaction becomes nonlinear, i.e. when Newton's superposition principle no longer holds. Starting from Maxwell's equations, the course develops the formalism of nonlinear optics by introducing the concept of nonlinear susceptibility explained using both a simple mechanical analogy and quantum mechanical perturbation theory. Topics include: coupled wave equations, 2nd and 3rd order nonlinear susceptibilities, nonlinear optical tensors, nonlinear crystals, phase matching, frequency conversion (sum frequency, second harmonic, difference frequency, parametric amplification, third harmonic generation), multiphoton absorption, intensity-dependent refractive index, self-focusing, self-phase modulation, nonlinear Schrödinger equation, stimulated Raman and Brillouin scattering, supercontinuum generation, and examples of extreme nonlinear optics.

Student Learning Outcomes

After successful completion of this course: Students will gain a solid theoretical basis in nonlinear optics as well as practical knowledge of nonlinear effects, nonlinear materials, and applications in various fields. This course will enable them to (1) distinguish between various nonlinear optical effects - three-photon, four-photon, etc.; (2) gain a clear understanding of how to select and orient a crystal, for example, to generate a sum frequency or second harmonic, and how to calculate the efficiency of nonlinear frequency conversion; (3) understand the positive and negative roles of nonlinear effects in crystals, optical fibers, waveguides, and other elements.

Course Materials and Resources

These textbooks are recommended but not required: R. W. Boyd, Nonlinear Optics, 3-rd (2008) or 4-th Edition (2020); G.I. Stegeman, R.A. Stegeman, Nonlinear Optics Phenomena, Materials, and Devices (Wiley, 2012) ; B.E.A. Saleh, M.C. Teich, Fundamentals of Photonics (Wiley 2007); A. Yariv, Quantum Electronics, 3-rd Edition, (Wiley 1989); Y.R. Shen, The Principles of Nonlinear Optics (Wiley 2003)

Course Assessment and Grading Procedure

Basis for the Final Grade:

Assessment	Percent of Final Grade

Homework (once a week)	33 %
Midterm Exam (open book)	33 %
Final Exam (in the form of a 10-min science presentation)	34 %
	100%

Assignment Schedule

Due Date	Assignment Name	Assignment Type	Points
1/8/25	Entry Quiz (does not affect the grade)	Quiz	1
1/16/25	Home work 1	Assignment	10
1/23/25	Home work 2.	Assignment	10
1/30/25	Home work 3.	Assignment	10
2/6/25	Home work 4.	Assignment	10
2/13/25	Home work 5.	Assignment	10
2/20/25	Home work 6.	Assignment	10
2/27/25	Home work 7.	Assignment	10
3/6/25	Home work 8.	Assignment	10
3/9/25	Home work 9 (simple Quiz)	Assignment	10
4/3/25	Home work 10.	Assignment	10
4/10/25	Home work 11.	Assignment	10
4/17/25	Home work 12.	Assignment	10

Grading Scale

Letter Grade	Percentage
A	94-100%

Letter Grade	Percentage
A-	90-93%
B+	87-89%
B	84-86%
B-	80-83%
C+	77-79%
C	74-76%
C-	70-73%
D+	67-69%
D	64-66%
D-	61-63%
F	0-60%

Policies for Course Grade

Makeup Work Policy: No makeups for the mid-term and final exams, which will be in person

Missed/Late Assignments: For each day of late submission, the grade will be reduced by 10%.

Attendance: Students will DRAMATICALLY benefit from personal interaction with the professor, so I encourage students to come to class in person.

Course Accessibility

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) (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.

Academic Integrity

Students should familiarize themselves with UCF's Code of Conduct at Student Conduct and Integrity Office. According to Section 1, "Academic Misconduct," students are prohibited from engaging in:

a. Academic misconduct is defined as any submitted work or behavior that obstructs the instructor of record's ability to accurately assess the student's understanding or completion of the course materials or degree requirements (e.g., assignment, quiz, and/or exam). Examples of academic misconduct include but are not limited to: plagiarism, unauthorized assistance to complete an academic exercise; unauthorized communication with others during an examination, course assignment, or project; falsifying or misrepresenting academic work; providing misleading information to create a personal advantage to complete course/degree requirements; or multiple submission(s) of academic work without permission of the instructor of record.

b. Any student who knowingly helps another violate academic behavior standards is also in violation of the standards.

c. Commercial Use of Academic Material. Selling of course material to another person and/or uploading course material to a third-party vendor without authorization or without the express written permission of the University and the instructor of record. Course materials include but are not limited to class notes, the instructor of record's slide deck, tests, quizzes, labs, instruction sheets, homework, study guides, and handouts.

d. Soliciting assistance with academic coursework and/or degree requirements. The solicitation of assistance with an assignment, lab, quiz, test, paper, etc., without authorization of the instructor of record or designee is prohibited. This includes but is not limited to asking for answers to a quiz, trading answers, or offering to pay another to complete an assignment. It is considered Academic Misconduct to solicit assistance with academic coursework and/or degree requirements, even if the solicitation did not yield actual assistance (for example, if there was no response to the solicitation).

Responses to Academic Dishonesty, Plagiarism, or Cheating

Students should also familiarize themselves with the procedures for academic misconduct in UCF's student handbook, *The Golden Rule*. 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 and Academic Integrity, 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.

Title IX

Title IX prohibits sex discrimination, including sexual misconduct, sexual violence, sexual harassment, and retaliation. If you or someone you know has been harassed or assaulted, you can find resources available to support the victim, including confidential

resources and information concerning reporting options at Let's Be Clear and UCF Cares.

For more information on diversity and inclusion, Title IX, accessibility, or UCF's complaint processes contact:

- Title IX – OIE – Office of Institutional Equity & askanadvocate@ucf.edu
- Disability Accommodation – Student Accessibility Services – Student Accessibility Services & sas@ucf.edu
- Access and Community Engagement (including the Ginsberg Center for Inclusion and Community Engagement, Military and Veteran Student Success, and HSI Initiatives)
- UCF Compliance and Ethics Office – Compliance, Ethics, and Risk Office & complianceandethics@ucf.edu
- The Ombuds Office is a safe place to discuss concerns.

Reporting an Incident or Issue

If you believe you have experienced abusive or discriminatory behavior by any faculty or staff member, contact the Office of Institutional Equity online or at 407-823-1336. You can also choose to report using the UCF Integrity Line and can report anonymously or as yourself at 1-855-877-6049 or using the online form. UCF cares about you and takes every report seriously. For more information see the Reporting an Incident or Issue Webpage.

Deployed Active-Duty Military Students

Students who are deployed active duty military and/or National Guard personnel and require accommodation should contact their instructors as soon as possible after the semester begins and/or after they receive notification of deployment to make related arrangements.

Campus Safety

At UCF Public Safety and Police, safety is the top priority. Emergencies on campus are rare, but if one should arise, it's important to be familiar with some basic safety and security concepts.

- In an emergency, always dial 911.
- Every UCF classroom has an **Emergency Procedure Guide** posted on a wall near the door, which will show you how to respond to a variety of situations. This guide can also be found online here.
- In the event of an active threat, remember **AVOID, DENY, DEFEND**. Choose the best course of action and act immediately. Watch the video here to learn more.
    - **AVOID**. Pay attention to your surroundings and have an exit plan. Get as much distance and as many barriers between you and the threat as quickly as possible.
    - **DENY.** When avoiding is difficult or impossible, deny the threat access to you and your space. Lockdown by creating barriers, turning the lights off and remaining quiet and out of sight. Make sure your cell phone is silenced, but do not turn it off.
    - **DEFEND.** When you are unable to put distance between yourself and the threat, be prepared to protect yourself. Commit to your actions, be aggressive and do not fight fairly. Do whatever it takes to survive.
- For emergencies on campus, UCF will utilize the UCF Alert system. All UCF students, faculty and staff are automatically enrolled to receive these email and text alerts, however, it's a good idea to frequently ensure your contact information is up to date.

Financial Aid Accountability

All instructors/faculty are required to document students' academic activity at the beginning of each course. In order to document that you began this course, please complete this activity by the end of the first week of classes or as soon as possible after adding the course. Failure to do so may result in a delay in the disbursement of your financial aid.

Class Schedule

Weekly Schedule, Spring 2025

Week	*Date*	*Lecture Title*
1	6-Jan	Lecture 1. Course logistics. Introduction to nonlinear optics.
2	8-Jan	Lecture 2. Math basics. Linear electrodynamics. Slowly varying envelope approximation.
3	13-Jan	Lecture 3. Nonlinear susceptibility of a classical anharmonic oscillator.
4	15-Jan	Lecture 4. Quantum-mechanical perturbation theory for the nonlinear optical susceptibility.
5	20-Jan	**Holiday, Martin Luther King Jr. day; no class**
6	22-Jan	Lecture 5. Coupled-wave equations.
7	27-Jan	Lecture 6. Sum-frequency and second-harmonic generation.
8	29-Jan	Lecture 7. Second-order nonlinear susceptibility $\chi^{(2)}$. Crystal classes. Electro-optic effect.
9	3-Feb	Lecture 8. Phase matching in nonlinear optical interactions
10	5-Feb	Lecture 9. Quasi-phase-matching (QPM).
11	10-Feb	Lecture 10. Conversion efficiency of the nonlinear optical processes.
12	12-Feb	Lecture 11. Difference-frequency generation.
13	17-Feb	Lecture 12. Optical parametric oscillators (OPOs) and amplifiers (OPAs).
14	19-Feb	Lecture 13. OPO tuning curves and bandwidth.
15	24-Feb	Lecture 14. Second-harmonic generation inside a resonator cavity.
16	26-Feb	Lecture 15. Frequency conversion using femtosecond optical pulses.
17	3-Mar	Lecture 16. Third-order nonlinear susceptibility $\chi^{(3)}$ and its tensor representation.
18	5-Mar	Lecture 17. Kerr effect. Intensity-dependent refractive index.
19	10-Mar	Refresher class for the midterm exam: solving problems, discussions, etc
20	12-Mar	**Midterm exam, open book**
21	17-Mar	**Spring Break**
22	19-Mar	**Spring Break**
23	24-Mar	Lecture 18. Self-focusing. Self-phase modulation. Pulse compression.
24	26-Mar	Lecture 19. Third harmonic generation. Parametric processes due to 4-wave mixing.
25	31-Mar	Lecture 20. Phase conjugation, optical limiting, all-optical switching. Two-

		and three-photon microscopy.
26	2-Apr	Lecture 21. Techniques for measuring 2^{nd} and 3^{rd} -order nonlinearities. Z-scan. Discussing topics for the Final Exam.
27	7-Apr	Lecture 22. Stimulated Brillouin scattering.
28	9-Apr	Lecture 23. Stimulated Raman scattering.
29	14-Apr	Lecture 24. Cascaded $\chi^{(2)}$ effects. Nonlinear Schrödinger equation.
30	16-Apr	Lecture 25. Conflicting NLO definitions. Guest Lecture.
31	21-Apr	Prepare for the Final Exam
32	23-Apr	**Final Exam (students' sci. talks)**
33	28-Apr	**Final Exam (students' sci. talks)**
34	30-Apr	**Final Grades by the Instructor**
35	2-May	Final Grades Officially Due before 12pm