CREOL OSE6334: Nonlinear Optics
College of Optics and Photonics
University of Central Florida

COURSE SYLLABUS

Instructor:	Dr. Konstantin Vodopyanov	Term:	Spring 2022
Office:	CREOL Room A113	Class Meeting Days:	Tue, Thu
Phone:	407 823 6818	Meeting Hours:	3:00–4:25 PM
E-Mail:	vodopyanov@creol.ucf.edu	Class Location:	Room 102
Website:	https://www.creol.ucf.edu/mir/		
Office Hours:	Fridays 5-6 pm (or by appointment)	TA:	n/a

I. Welcome!

Welcome to the CREOL OSE6334 course: Nonlinear Optics.

II. University Course Catalog Description:

Maxwell's equations in nonlinear media, frequency conversion techniques (SHG, SFG, OPO), stimulated scattering, phase conjugation, wave-guided optics, nonlinear crystals.

III. Course Description:

This course studies the interaction of *intense* light with the optically transparent matter when the interaction becomes nonlinear, that is when Newton's principle of superposition is no longer valid. Starting with Maxwell's equations, the course develops the formalism of nonlinear optics, introducing the concept of nonlinear susceptibility explained using both 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 generation, optical parametric oscillation), multiphoton absorption, intensity-dependent refractive index, self-focusing, nonlinear Schrödinger equation, stimulated Raman and Brillouin scattering, supercontinuum generation, and a few examples of extreme nonlinear optics.

IV. Learning Outcomes:

Students will gain the theoretical foundations of nonlinear optics, as well as practical knowledge of nonlinear effects, nonlinear materials, and applications in various fields. This course will allow (1) to distinguish between different nonlinear optical effects - three-photon, four-photon, etc.; (2) get a clear idea of how to select and orient a crystal for a frequency conversion application; (3) understand the positive and negative role of nonlinear effects in optical media, including fibers and waveguides.

V. Course Prerequisites

OSE 6111 Optical Wave Propagation

VI. Course Credits:

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VII. Main textbook:

R. W. Boyd, Nonlinear Optics, 3-rd Ed. (Academic Press, 2008) or 4-th Ed. (Elsevier, 2020)
G.I. Stegeman, R.A. Stegeman, Nonlinear Optics Phenomena, Materials, and Devices (Wiley, 2012)

VIII. Other textbooks:

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)

IX. Basis for Final Grade:

Assessment	Percent of Final Grade
Homework (once a week)	35 %
Midterm Exam (open book)	35 %
Final Exam (in the form of 10-min presentation)	30 %
	100%

Grading scale:

Grading Scale (%)	
94-100	A
90-93	A-
87-89	B+
84-86	B
80-83	B-
77-79	C+
74-76	C
70-73	C-
67-69	D+
64-66	D
60-63	D-

Grading Scale (%)	
0 - 59	F

X. 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 "myUCF Grades" in the portal. Please note that scores returned mid-semester are unofficial grades. If you need help accessing myUCF Grades, see the online tutorial: https://myucfgrades.ucf.edu/help/.

XI. Course Policies: Grades

Late Work Policy: There are no make-ups for the homework, or the final exam. Late homework submission penalty: 10% will be deduced for each day of the delay.

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*. 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.

XII. Course Policies: Technology and Media

Email: Please use email *vodopyanov@creol.ucf.edu* for all correspondence.

Website: All information concerning the course will be posted on WebCourses. This site will reflect latest changes, contain some key scientific papers, as well as lecture handouts that will be posted for each lecture the day before the lecture (may be very late evening).

XIII. Course Policies: Student Expectations

Disability Access: The University of Central Florida is committed to providing reasonable accommodations for all persons with disabilities. Students with disabilities who need accommodations in this course must contact the professor at the beginning of the semester to discuss needed accommodations. No accommodations will be provided until the student has met with the professor to request accommodations. Students who need accommodations must be registered with Student Disability Services, Student Resource Center Room 132, phone (407) 823-2371, TTY/TDD only phone (407) 823-2116, before requesting accommodations from the professor.

Attendance Policy:
This is a face to face class. Student's attendance is required (wear masks!). Students must be on time to class. If a student cannot attend a class for a valid reason, he/she can access the material via a recorded file (PowerPoint with narration on webcourses).

Professionalism Policy:
Per university policy and classroom etiquette; mobile phones must be silenced during all classroom lectures. Those not following this rule will be asked to leave the classroom immediately so as to not disrupt the learning environment.

XIV. Schedule, Spring 2022

1	11-Jan	Lecture 1. Course logistics. Introduction to nonlinear optics. Complex-number math.
2	13-Jan	Lecture 2. Maxwell's equations in nonlinear media. Slowly varying envelope approximation.
3	18-Jan	Lecture 3. Nonlinear susceptibility based on a classical anharmonic oscillator approach.
4	20-Jan	Lecture 4. Nonlinear susceptibility based on the quantum-mechanical perturbation theory.
5	25-Jan	Lecture 5. Coupled-wave equations for nonlinear optical interactions.
6	27-Jan	Lecture 6. Sum-frequency and 2nd-harmonic generation.
7	1-Feb	Lecture 7. Nonlinear optical crystals with 2nd-order susceptibility
8	3-Feb	Lecture 8. Phase matching in nonlinear optical interactions
9	8-Feb	Lecture 9. Quasi-phase-matching (QPM).
10	10-Feb	Lecture 10. Conversion efficiency of a nonlinear optical process.
11	15-Feb	Lecture 11. Difference-frequency generation.
12	17-Feb	Lecture 12. Optical parametric oscillators (OPOs) and amplifiers (OPAs).
13	22-Feb	Lecture 13. OPO tuning curves and gain bandwidth.
14	24-Feb	Lecture 14. 2nd harmonic generation inside a resonator cavity.
17	1-Mar	Preparing for Midterm exam. Tips on problem solving.
16	3-Mar	**Midterm exam, open book**
15	8-Mar	**Spring Break**
18	10-Mar	**Spring Break**
19	15-Mar	Discussion: midterm exam
20	17-Mar	Lecture 15. Frequency conversion using ultrafast optical pulses.
21	22-Mar	Lecture 16. 3rd-order nonlinear susceptibility $\chi^{(3)}$ and its tensor representation.
22	24-Mar	Lecture 17. Kerr effect. Intensity-dependent refractive index.
23	29-Mar	Lecture 18. Self-focusing. Self-phase modulation. Nonlinear Schrödinger equation.
24	31-Mar	Lecture 19. 3rd harmonic generation. Parametric processes due to 4-wave mixing.
25	5-Apr	Lecture 20. Phase conjugation, optical limiting, all-optical switching. Two- and three-photon microscopy.
26	7-Apr	Lecture 21. Techniques for measuring 2nd and 3rd -order nonlinearities. Z-scan.
27	12-Apr	Lecture 22. Cascaded $\chi^{(2)}$ effects and nonlinear phase shift.
27	14-Apr	Lecture 23. Stimulated Raman scattering. Discussing topics for the Final Exam.
29	19-Apr	Lecture 24. Stimulated Brillouin scattering. Discussing topics for the Final Exam.
30	21-Apr	Lecture 25. Guest lecture: "Extreme nonlinear optics and high-field interactions". Discussing topics for the Final Exam.
31	26-Apr	**Final Exam (students' talks, 10 min) part 1**
32	28-Apr	**Final Exam (students' talks, 10 min) part 2**
33	**3-May**	**Final Grades**