University of Illinois at Urbana-Champaign
Department of Electrical and Computer Engineering
ECE 570 – Nonlinear Optics (4 credits)
Course Syllabus

Course Description:
Nonlinear optics allows us to change the color of a light beam, to change its shape in space and time, and to create the shortest events ever made by humans. Nonlinear optical phenomena are the basis of many components of optical communications systems, optical sensing, biomedical imaging, and materials research. This course introduces the fundamentals and applications of nonlinear interaction of radiation with matter. The goal is to provide working knowledge of nonlinear effects, nonlinear materials and the applications of nonlinear optics in various technologies.

Prerequisites: ECE 520, or ECE 598YZ, or consent of the instructor.

Requirements: ECE major, graduate level course.

Professor: Dr. Yang Zhao
Office Location:
Holonyak Micro and Nanotechnology Lab, Rm 1106
208 N. Wright Street
Urbana, IL 61801
Office Hours: 11:00-12:00 on Tuesdays
Email: yzhaoui@illinois.edu

Teaching Assistants: Tobby Qiu

Lecture: This class will meet every Tue & Thu 2:00pm-3:20pm.

Course website: Canvas

Zoom link:
https://illinois.zoom.us/j/87601692718?pwd=dliwRusYSjUiXWSR2zwTm8a1vxUP6a.1&from=addon

Course Objectives:
This class aims to provide a rigorous introduction to light-matter interactions through nonlinear processes mainly using classical optics approaches. We will also study quantum mechanical foundations of nonlinearities. With this fundamental knowledge, I will introduce applications of nonlinear optics for example, in spectroscopy and imaging.

List of Topics:
Several main topics of nonlinear optics will be covered in this course.

Outline:

Pre: Introduction to Linear Optics

I: Second Order Phenomena

- Second order susceptibility, $\chi^{(2)}$
- Coupled Wave Equations
- Phase-matching
- Susceptibility Tensor
- Second-harmonic Generation (SHG)
- Three Wave Mixing
- Optical Parametric Amplifiers and Oscillators
- $\chi^{(2)}$ Nonlinear Materials

II: Nonlinear Susceptibilities

- Perturbation Theory of Susceptibilities

III: Third Order Phenomena

- Third Order Susceptibilities
- Nonlinear Refraction and Absorption
- $\chi^{(3)}$ Nonlinear Materials
- Solitons (optional)
- Four-Wave Mixing (optional)
- Mechanisms for NLR & NLA
- Nonlinear Spectroscopy
- Stimulated Scattering (optional)

Textbook:
There are **no required** textbooks for this course. Any required readings for a lecture will be posted on the course website as a pdf file. Students who desire supplementary reading for further detail can use the following textbook:

- "Nonlinear Optics, phenomena, materials and devices", George & Robert Stegeman, Wiley Series in Pure and Applied Optics, Glenn Boreman, Series editor, 2012. (Recommended)
- "Nonlinear Optics", Robert Boyd, Academic Press. (Optional)

Exams:
There will be two mid-term exams.
Mid-term 1 is in person during class time (open-book, open-notes).
Mid-term 2 is a take-home exam, due 24 hours after posting.
The exams will account for 30% of the final grade. There will be no final exam. **No use of cell phones, computers, or other personal electronics is allowed in the in-class exam. No discussions among students, nor AI usage, are allowed for the take-home exam.** Violating these rules during an exam may be considered a violation of the student code of conduct.

Final Presentation:

There will be a final presentation that accounts for 15% of the final grade (the equivalent of one normal final exam). The final few lectures will be reserved for in-class (and zoom) student presentations. Questions to the presenters will count toward the 3% grade included in the final presentation grade. Title/paper selection is due one-week before the s Peer-evaluation forms will count for the 2% grade. You will submit one evaluation form for each presentation day, excluding self-evaluation (we will discuss the form when coming close to the presentation days).

Homework:
There will be 6 homework assignments. New homework is normally posted on every other Tuesday, and due by Tuesday end of the day (11:59PM CST) on **Gradescope**. You have ~2 weeks to work on each homework. *You can drop the lowest grade homework*; the total homework accounts for 50% of the final grade.

Late Submission Policy:
Late homework submission **is allowed**. Late homework within 24 hours after the due date will be given a 10% grade deduction. Late homework by 24 hours to 48 hours will be given a 50% grade deduction. Homework late for more than 48 hours will not be accepted.

Contesting Grades:
If you feel that your assignment or exam has been graded inappropriately, you are welcome to contest grades via a written statement within one week of receiving the graded assignment. To contest a grade, you must submit a written statement (preferably via email) of what you believe was graded incorrectly and why the grade should be altered. No oral contesting of grades will be considered, nor will we consider any contest of grades submitted after one week. Note, that contesting a grade means the item in question will be completely regraded, which may result in a lower grade overall.

Final Grade Breakdown:

Midterm 1	15%
Midterm 2	15%
Final presentation (including 3% for questions to others, 2% for peer-evaluation form)	15%
In-class participation	5 % (attendance)
Homework 1	10 %
Homework 2	10 %
Homework 3	10 %
Homework 4	10 %
Homework 5	10 %
Homework 6	10%
Total	**100 %** (by dropping the lowest HW)

Course Grading Philosophy:
I. I use the following grade system. Depending on the distribution of points at the end of the semester I may drop the cut-off points slightly (e.g., 85% might become the A cut-off) but I will not raise the cut-offs; I will not "curve" the exams or assignments.

A+	>= 95%
A	90% to <95%
A-	85% to <90%
B+	80% to <85%
B	75% to <80%
B-	70% to <75%
C+	67% to <70%
C	63% to <67%
C-	60% to <63%
D+	57% to <60%
D	53% to <57%
D-	50% to <53%
F	<50%

II. To get the 5% participation*, the student will need to attend at least 90% of the lectures**.
*Participation in class will account for 5% of the final grade.
**Students are encouraged to contact the instructor directly to discuss their absence due to illness/medical conditions or conference travels.

Course Calendar (Spring 2026):

Lecture	Date	Topic	Comments
1	1/20	Review of Linear Optics (ECE 529. Light-Matter Interaction)	HW 1 posted
2	1/22	Chapter 1. Introduction to Nonlinear Optics	
3	1/27	Chapter 2. Second Order Susceptibility	
4	1/29	Chapter 2. Second Order Susceptibility II, Chapter 3. Coupled Wave Equations for Generating New Frequencies I	
5	2/3	Chapter 3. Coupled Wave Equations for Generating New Frequencies II	HW 1 due /HW 2 posted

6	2/5	Chapter 3. Coupled Wave Equations for Generating New Frequencies III	
7	2/10	Chapter 4. Phase Matching	
8	2/12	Chapter 4. QPM SHG Engineering and partially	
9	2/17	Chapter 5. Susceptibility Tensor I	HW 2 due /HW 3 posted
10	2/19	Chapter 5. Susceptibility Tensor II	
11	2/24	Chapter 6. High SHG Conversion Efficiency and Complexities in SHG	
12	2/26	Chapter 6. High SHG Conversion Efficiency and Complexities in SHG II	
13	3/3	Chapter 7. Finite beams (Pre-recorded lecture)	Instructor is out of town, watch the recording before the next lecture HW 3 due /HW 4 posted
14	3/5	Chapter 8. Nonlinear Modes Three-Wave Mixing Processes	
	3/10	Chapter 9. OPA	
15	3/12	Mid-term 1, in class	
	3/17	Spring Break	
	3/19	Spring Break	
16	3/24	Chapter 9. OPO	Go over mid-term solutions /HW 4 due /HW 5 posted
17	3/26	Chapter 10. Nonlinear materials	
18	3/31	Chapter 11. Quantum mechanics description of susceptibility I	

19	4/2	Chapter 11. Quantum mechanics description of susceptibility II	
20	4/7	Chapter 11. Quantum mechanics description of susceptibility III	HW 5 due /HW 6 posted
21	4/9	Chapter 12. Third order effects I	
22	4/14	Chapter 12. Third order effects II	
23	4/16	Chapter 13. NLA and NLR I	Presentation paper topic due
24	4/21	Chapter 13. NLA and NLR II Chapter 15. Measurement of X3	Chapter 14. NLA/NLR applications (Optional) HW 6 due
25	4/23	Final Presentation Midterm 2 (take home exam, due in 24 hours)	Normal class time presentations (in person)
26	4/28	Final Presentation	Instructor out of town, presentations will be arranged to evening on Zoom, link will be sent through emails and posted on Canvas
27	4/30	Final Presentation	Instructor out of town, presentations will be arranged to evening on Zoom, link will be sent through emails and posted on Canvas
28	5/5	Final Presentation	Normal class time presentations (in person)

Course Website:
We will use Canvas for the course website. As an enrolled student, you will have access to the course website. If you do not have access, contact your TA (TBD) immediately.

What you will find on the course website:

- The syllabus for lecture
- Course calendar
- Updates from the instructor and/or TAs
- Resources, lecture notes, and handouts.

Course Policies:
All students are assumed to have read and understood the "Code of Policies and Regulations Applying to All Students," University of Illinois, and will be expected to act accordingly. The Code is available online at:
http://www.admin.uiuc.edu/policy/code/index.html

Academic Integrity:
According to the Student Code, 'It is the responsibility of each student to refrain from infractions of academic integrity, from conduct that may lead to suspicion of such infractions, and from conduct that aids others in such infractions.' Please know that it is my responsibility as an instructor to uphold the academic integrity policy of the University, which can be found here: http://studentcode.illinois.edu/article1_part4_1-401.html

Disabilities and Religious Observances:
Please contact your instructors or TAs during the first week of classes to make requests for disability accommodations or observation of religious holidays.

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES you may visit 1207 S. Oak St., Champaign, call 333-4603 (V/TTY), or e-mail a message to disability@illinois.edu

To obtain waivers for student athlete (cheerleader, marching band, etc.) activities, submit your documentation in person during the first week of class.

Emergency Response Recommendations:
The Department of Homeland Security and the University of Illinois at Urbana-Champaign Office of Campus Emergency Planning recommend the following three responses to any emergency on campus: RUN> HIDE > FIGHT. Please refer to the following websites for more detail:
https://www.dhs.gov/sites/default/files/publications/active_shooter_pocket_card_508.pdf
https://police.illinois.edu/emergency-preparedness/campus-emergency-operations-plan/