UNIVERSITY OF CENTRAL FLORIDA

OSE 6335 - NONLINEAR GUIDED WAVE OPTICS

Section: 0001

Optics and Photonics

Course Information

Term: Spring 2025
Class Meeting Days: TR
Class Meeting Time: 03:00PM - 04:15PM
Class Meeting Location: CROL A214
Modality: P
Credit Hours: 3.00

Instructor Information

Andrea Blanco Redondo
Title: Professor
Office Location: CROL 210
Office Hours:
Tuesday and Thursday from 1:30 to 2:30 pm
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Course Description

OSE 6335 OPT-OPT 3(3,0)Nonlinear Guided Wave Optics: PR: Graduate standing and OSE 6334C or C.I. The physics and applications of nonlinear optical interactions in fibers and planar waveguides is discussed, including parametric processes, all-optical effects and solitons. Even Fall.

This course aims to give students a comprehensive understanding of pulse propagation through optical waveguides, a crucial matter for most aspects of modern optics and photonics, including optical communications, ultrafast lasers, and quantum optics. It focuses on media with dominant third-order nonlinear ($\chi^{(3)}$) effects, such as silica optical fibers and silicon photonic waveguides, which are of great practical importance.

We will begin by a general introduction of nonlinear optics, followed by reviewing the fundamentals of optical fibers and integrated optical waveguides, introducing the effects of attenuation, dispersion, and nonlinearity. Next, we will obtain the basic equation that governs pulse propagation in optical waveguides and will work together on building a code to solve this equation. This code will be used by the students throughout the rest of the course as a tool to understand the effects highlighted above and their fascinating interplay.

Armed with this powerful tool we will delve deeper in the concepts of chromatic dispersion –different frequencies travelling at different speeds – and nonlinear refraction – the intensity dependence of the refractive index. Building on these foundations we will then cover many important phenomena such as dispersive pulse broadening, self-phase modulation, optical solitons, cross-phase modulation, four-wave mixing, and supercontinuum generation.

Subsequently, we will discuss nonlinear effects that are especially important in optical fibers: stimulated Raman and Brillouin scattering. This class of nonlinear effects result from stimulated inelastic scattering, in other words, from the optical field transferring part of its energy to the medium.

Analogously, semiconductor photonic waveguides showcase their own specific nonlinearities, such as two-photon absorption and free-carrier nonlinearities, which we will also discuss in this course.

After covering the fundamentals, we will examine some specific applications of the phenomena covered above, such as ultrafast soliton lasers, the generation of entangled photons through four-wave mixing, and supercontinuum sources for spectroscopy and sensing.

Towards the end of the course the students will work on a research topic of their choice, by choosing a paper, reproducing its results using simulations, and, perhaps, from there finding new unexplored research directions.

Student Learning Outcomes

After successful completion of this course, students will be able to:

- Simulate pulse propagation in optical waveguides (optical fibers and integrated photonic waveguides) in realistic environments, such as communication links, laser cavities, and sources of quantum light.
- Understand the origin and the consequences of the frequency dependence of the refractive index – dispersion.
- Understand the origin and the consequences of the intensity dependence of the refractive index – nonlinear refraction.
- Explain the fascinating and pervasive phenomenon of optical solitons, originating from the balance of dispersion and nonlinearity.
- Explain nonlinear phenomena involving several waves such as four-wave mixing and cross-phase modulation.
- Comprehend the importance of nonlinear optics and the crucial role it plays in real life applications.

Course Materials and Resources

Nonlinear Fiber Optics
ISBN: 978-0-12397-023-7
Authors: Govind Agrawal
Publisher: Academic Press

Course Assessment and Grading Procedure

The course will be graded based on homework assignments and a final presentation.

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

This is an indicative distribution of the topics covered per week:

Week	Topic
1	Introduction to nonlinear optics in waveguides; Introduction to optical fibers

Week	Topic
2	Introduction to integrated photonic waveguides (focusing in $\chi^{(3)}$ media); Pulse Propagation Equation
3	Solving the pulse propagation equation: Numerical methods - split-step Fourier method and finite differences; Start writing your own code.
4	Chromatic dispersion: chirp, group velocity dispersion, pulse broadening, high orders of dispersion.
5	Nonlinear refraction; Self-phase modulation (SPM): nonlinearly induced spectral changes, interplay with dispersion.
6	Self-phase modulation (SPM): optical wave breaking, higher-order nonlinear effects;
7	Optical solitons: modulation instability, fundamental solitons, higher-order solitons; Dispersion-managed and dissipative solitons.
8	Infinite hierarchy of solitons: Interaction of Kerr nonlinearity with even orders of dispersion.
9	Cross-phase modulation (XPM): XPM-induced nonlinear coupling, XPM-induced modulation instability, XPM-paired solitons
10	Four-wave mixing (FWM): origin, theory, phase-matching techniques, parametric amplification
11	Stimulated Raman Scattering (SRS) and Stimulated Brillouin Scattering (SBS): origin, Raman/Brillouin-gain spectrum, Raman/Brillouin threshold, coupled amplitude equations, Raman and Brillouin amplification
12	Nonlinear optical phenomena in silicon waveguides: the impact of two-photon absorption and free-carriers.
13	Applications: Ultrafast lasers – Mode-locked lasers, soliton lasers, similariton lasers, all-normal dispersion lasers.
14	Applications: Supercontinuum sources – soliton fission and dispersive waves, supercontinuum generation with picosecond and femtosecond pulses, optical Rogue waves
15	Applications: Quantum optics – generation of entangled states of light, strong interactions between individual photons
16	Latest research topics; Group presentations