CREOL, The College of Optics and Photonics
UNIVERSITY OF CENTRAL FLORIDA

Course Syllabus

OSE6211 Imaging & Optical Systems, 3 Cr

Instructor:	Bahaa Saleh	**Term:**	Spring 2021
Email:	besaleh@creol.ucf.edu	**Class Meeting Days:**	Tuesday, Thursday
Phone:	407 882-3326	**Class Meeting Time:**	10:30–11:15 pm
Office:	CREOL Rm 207	**Class Location**	zoom
Office Hours:	T, R 1:00-2:00 pm	**Website:**	Webcourse
Zoom pass:	1b788k		

Course Catalog Description:
Imaging and Optical Systems: PR: Admitted to a graduate program in Optics, Physics or Electrical Engineering, or C.I. Linear systems theory of discrete and continuous one- and two-dimensional systems. Applications to optical polarization, pulse propagation, and image formation.

Prerequisites: Graduate standing or consent of instructor

Detailed Description:
This course provides an introduction to optical and imaging systems based on a foundation of linear vector space, matrix theory, discrete and continuous one- and two-dimensional linear systems, and the basic theory of random vectors and random functions. An underlying theme is the concept of modes. Discrete optical systems include propagation of rays through optical components and resonators, polarization devices, spatial modes, coupled waveguides, beam splitters, and multilayered systems. Continuous systems include pulse propagation in a dispersive medium, beam propagation in free space, coherent imaging systems and Fourier optics, and tomographic imaging based on projections. An introduction to random fields and their transmission through discrete and continuous optical systems follows with applications to incoherent imaging systems.

List of Topics: See list on page 3

Textbook:
None (Class notes will be posted ahead of lectures)

Recommended Reference:
B. Saleh and M. Teich, Fundamentals of Photonics, 3rd edition, Wiley, 2019

Other required course material
None

Course Credits: 3

Course Grading:
Homework (20%), midterm exam (30%), final exam (50%)

Make up Exam 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

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, please complete the following academic activity by the end of the first week of classes, or as soon as possible after adding the course, but no later than August 27. Failure to do so will result in a delay in the disbursement of your financial aid.

Grade	Rubric Description
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.
B	Good, has a strong understanding of most or all of the concepts and is able to apply them to stated and defined situations.
C	Average, has a basic understanding of the major concepts of the course and is able to apply to basic situations.
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 situtations.
F	Demonstrates no understanding of the course content.

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.

Class Website:
Materials used for classes will be available on UCF Webcourses for download before each class or distributed during class.

Important dates:

Classes begin   January 11, 2021
Withdrawal date   March 26, 2021
MLK Day   January 18, 2021
Spring break   April 11-18, 2021
Classes end   April 26, 2021
Final exam period   May, 28-May 4, 2021
Final exam   May, 4 , 2021 10:00am - 12:50 pm

1. Linear Algebra: Brief Introduction
3 lectures

1.1 **Vector spaces**: Euclidean space, sequence space, and function space. Normed and inner-product spaces. Bases and dimension. Hilbert space.

1.2 **Linear mappings and operators**. Hermitian, unitary & projection operators. Functionals

1.3 **Eigenvectors and eigenvalues**. Spectral theorem. Modes

1.4 **Representations** of vectors and operators in a basis.

1.5 **Dirac notations**

2. Finite-Dimensional Linear Systems
5 lectures

2.1 **Binary systems**. 2×2 Matrix representation. Poincare sphere. Modes. Cascaded and periodic systems

2.2 **Matrix optics examples**

  A. Ray optics of lenses and mirrors and resonators   Ray-transfer matrix

  B. Ray optics of periodic systems. Optical resonators

  C. Polarization devices

  D. Two coupled waveguides

  E. Reflection & transmission at a boundary. Scattering matrix. Lossless beam splitter. Mach Zehnder Interferometer

  F. Wave propagation in multilayered media. Wave-transfer matrix

  G. Wave propagation in periodic media. Photonic crystals

2.3 **M-dimensional systems**: Matrix representation. Transforms (Discrete Fourier transform, Hadamard transform)

2.4 **Examples of finite dimensional optical systems**

  A. Array of coupled waveguides

  B. Discrete time signals (sampled video)

3. Temporal Linear Systems
3 lectures

3.1 **Linear integral transforms** as operators on functions of a continuous variable (e.g., optical pulse) in Hilbert space

3.2 **Linear shift-invariant (LSI) systems**. Impulse response function. Convolution Harmonic functions as modes of LSI system. Expansion of an *arbitrary* 1D function in a basis of harmonic functions. Fourier transform. Transfer function.

3.3 **Examples of LSI optical system**

  A. Detection of an optical pulse

  B. Propagation of an optical pulse in dispersive medium. Group velocity dispersion

  C. Optical pulse compression

4. Spatial Linear Systems   4 lectures

4.1 **Linear integral transforms** as operators on functions of 2 continuous variables (e.g., an image) in Hilbert space

4.2 **Linear shift-invariant (LSI) systems.** Point spread function (PSF). Convolution. Harmonic functions as modes of LSI system. Expansion of an *arbitrary* 2D function in a basis of 2D harmonic functions. 2D Fourier transform. Transfer function

4.3 **Image processing**: spatial filtering, image enhancement, image restoration

4.4 **Projection operators**. Projection-slice theorem. Radon transform
      CT tomography

5. Coherent Optical Systems   4 lectures

5.1 **Wave propagation** between two planes in free space as a linear system. Transfer function

5.2 **Fresnel diffraction**. Analogy between Fresnel diffraction and second-order dispersion
      Talbot imaging

5.3. **Fraunhofer diffraction**

5.4. **Optical Fourier transform** with a single lens. Optical spatial filters

5.5. **Image formation**. PSF and optical transfer function (OTF). Resolution

6. Systems Described by Linear Differential Equations   3 lectures

6.1 **Operators described by linear differential equations**
      A. Helmholtz equation: planar waves, spatially-invariant superpositions of planar waves
      B. Paraxial Helmholtz equation: Hermite-Gaussian modes, Laguerre-Gaussian modes
      C. Waves in a periodic medium. Bloch modes and band structure

6.2 **Systems described by linear differential equations and boundary conditions**
      A. Schrödinger equation: modes of a quantum well
      B. Paraxial Helmholtz equation: modes of an optical resonator
      C. Helmholtz equation: modes of an optical waveguide

7. Random Vectors in Linear Systems   4 lectures

7.1 **Statistics of finite-dimensional random vectors**: correlation matrix
      Partial polarization

7.2 **Statistics of random function**: correlation function, power spectral density
      Partial coherence

7.3 **Transmission through linear systems**. Effect on correlation
      A. Transmission of partially polarized light through polarization devices
      B. Image formation with incoherent light. Modulation transfer function (MTF)
      C. Image formation in laser scanning fluorescence microscopy & confocal microscopy

7.4 **Fourier-transform of a random function**
      Imaging of an incoherent source by measurement of correlation function

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Total   27

Academic Integrity

Students should familiarize themselves with UCF's Rules of Conduct at
http://osc.sdes.ucf.edu/process/roc. 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.

For more information about Academic Integrity, consult the International Center for Academic Integrity
http://academicintegrity.org. For more information about plagiarism and misuse of sources, see "Defining
and Avoiding Plagiarism: The WPA Statement on Best Practices" http://wpacouncil.org/node/9.

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 http://goldenrule.sdes.ucf.edu/docs/goldenrule.pdf . UCF faculty
members have a responsibility for students' education and the value of a UCF degree, and so seek to
prevent unethical behavior and when necessary respond to academic misconduct. Penalties can include a
failing grade in an assignment or in the course, suspension or expulsion from the university, and/or a "Z
Designation" on a student's official transcript indicating academic dishonesty, where the final grade for
this course will be preceded by the letter Z. For more information about the Z Designation, see
http://goldenrule.sdes.ucf.edu/zgrade.

Course Accessibility

The University of Central Florida is committed to providing access and inclusion for all persons with
disabilities. Students with disabilities who need disability-related access in this course 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). Through Student
Accessibility Services, a Course Accessibility Letter may be created and sent to professors, which informs
faculty of potential access and accommodations that might be 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.

Campus Safety

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.

1. In case of an emergency, dial 911 for assistance.

2. 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 http://emergency.ucf.edu/emergency_guide.html.
3. Students should know the evacuation routes from each of their classrooms and have a plan for finding safety in case of an emergency.
4. 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 http://www.ehs.ucf.edu/AEDlocations-UCF (click on link from menu on left).
5. 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."
6. Students with special needs related to emergency situations should speak with their instructors outside of class.
7. To learn about how to manage an active-shooter situation on campus or elsewhere, consider viewing this video https://youtu.be/NIKYajEx4pk.

Make-Up Assignments for Authorized University Events or Co-curricular Activities
Students who represent the university in an authorized event or activity (for example, student-athletes) and who are unable to meet a course deadline due to a conflict with that event must provide the instructor with documentation in advance to arrange a make-up. No penalty will be applied. For more information, see the UCF policy at http://policies.ucf.edu/documents/4-401.1MakeupAssignmentsForAuthorizedUniversityEventsOrCocurricularActivities.pdf

Religious Observances
Students must notify their instructor in advance if they intend to miss class for a religious observance. For more information, see the UCF policy at http://regulations.ucf.edu/chapter5/documents/5.020ReligiousObservancesFINALOct17.pdf.

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.

University-Wide Face Covering Policy for Common Spaces and Face-to-Face Classes
To protect members of our community, everyone is required to wear a facial covering inside all common spaces including classrooms (https://policies.ucf.edu/documents/PolicyEmergencyCOVIDReturnPolicy.pdf). Students who choose not to wear facial coverings will be asked to leave the classroom by the instructor. If they refuse to leave the classroom or put on a facial covering, they may be considered disruptive (please see the Golden Rule for student behavior expectations). Faculty have the right to cancel class if the safety and well-being of class members are in jeopardy. Students will be responsible for the material that would have been covered in class as provided by the instructor.

Notifications in Case of Changes to Course Modality
Depending on the course of the pandemic during the semester, the university may make changes to the way classes are offered. If that happens, please look for announcements or messages in Webcourses@UCF or Knights email about changes specific to this course.

COVID-19 and Illness Notification
Students who believe they may have a COVID-19 diagnosis should contact UCF Student Health Services (407-823-2509) so that proper contact tracing procedures can take place.
Students should not come to campus if they are ill, are experiencing any symptoms of COVID-19, have tested positive for COVID, or if anyone living in their residence has tested positive or is sick with COVID-19 symptoms. CDC guidance for COVID-19 symptoms is located here: https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html.
Students should contact their instructor(s) as soon as possible if they miss class for any illness reason to discuss reasonable adjustments that might need to be made. When possible, students should contact their instructor(s) before missing class.

In Case of Faculty Illness
If the instructor falls ill during the semester, there may be changes to this course, including having a backup instructor taking over the course. Please look for announcements or messages in Webcourses@UCF or Knights email for any alterations to this course.

Course Accessibility and Disability for COVID-19
Accommodations may need to be added or adjusted should this course shift from an on-campus to a remote format. Students with disabilities should speak with their instructor and should contact sas@ucf.edu to discuss specific accommodations.