CREOL, The College of Optics and Photonics

UNIVERSITY OF CENTRAL FLORIDA

Course Syllabus

OSE6211 Imaging & Optical Systems, 3 Cr

Instructor:	Bahaa Saleh	**Term:**	Fall 2017
Email:	besaleh@creol.ucf.edu	**Class Meeting Days:**	Tuesday, Thursday
Phone:	407 882-3326	**Class Meeting Time:**	3:00–4:15 pm
Office:	CREOL Rm 207	**Class Location**	CREOL 102
Office Hours:	T, R 2:00-3:00 pm+	**Website:**	Webcourse

+ I will be in my office at these times, but of course I will be happy to discuss the material with you anytime. I often get questions via e-mail that can be quickly answered.

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 algebra, 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 of the system. Discrete optical systems include propagation of a ray through optical components and resonators, polarization devices, 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 tomographic imagery based on projections. Systems described by differential equations with boundary conditions are used to determine the energy levels of a simple quantum well and modes of an optical waveguide. An introduction to random signals and their transmission through discrete and continuous optical systems follows.

List of Topics: See attached list

Textbook:
None (Class notes will be provided)

Recommended Reference:
B. Saleh and M. Teich, Fundamentals of Photonics, Wiley, 2007

Other required course material
None

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.

Professionalism and Ethics:
Per university policy and plain classroom etiquette, mobile phones, etc. must be silenced during all classroom lectures, unless you are specifically asked to make use of such devices for certain activities. Academic dishonesty in any form will not be tolerated! If you are uncertain as to what constitutes academic dishonesty, please consult The Golden Rule in the UCF Student Handbook (www.goldenrule.sdes.ucf.edu) for further details. As in all University courses, The Golden Rule Rules of Conduct will be applied. Violations of these rules will result in a record of the infraction being placed in your file and the student receiving a zero on the work in question AT A MINIMUM. At the instructor's discretion, you may also receive a failing grade for the course. Confirmation of such incidents can also result in expulsion from the University.

Students with Special Testing/Learning Needs:
Students with special needs and require special accommodations must be registered with UCF Student Disability Services prior to receiving those accommodations. Students must have documented disabilities requiring the special accommodations and must meet with the instructor to discuss the special needs as early as possible in the first week of classes. UCF Student Disability Services can be contacted at www.sds.sdes.ucf.edu or at (407) 823-2371.

Detailed list of topics

OSE 6211 **IMAGING AND OPTICAL SYSTEMS** Fall 2017

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**

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-ary 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

Daily Schedule (subject to change):

Week	Date	Course material:
1	T 8/22	1. Linear Algebra
	R 8/24	
2	T 8/29	
	R 8/31	No class, Football Day
3	T 9/5	2. Finite-Dimensional Linear Systems
	R 9/7	
4	T 9/12	
	R 9/14	
5	T 9/19	
	R 9/21	3. Temporal Linear Systems
6	T 9/26	
	R 9/28	
7	T 10/3	4. Spatial Linear Systems
	R 10/5	
8	T 10/10	Midterm Exam
	R 10/12	
9	T 10/17	
	R 10/19	5. Coherent Optical Systems
10	T 10/24	
	R 10/26	
11	T 10/31	
	R 11/2	6. Systems Described by Differential Equation
12	T 11/7	
	R 11/9	
13	T 11/14	
	R 11/16	7. Random Vectors in Linear Systems
14	T 11/21	
	R 11/23	Thanksgiving
15	T 11/28	
	R 11/30	
	R 12/7	FINAL EXAM 1:00–3:50 pm