USC Viterbi School of Engineering

Ming Hsieh Department of Electrical Engineering

Course Announcement

EE 566: Optical Information Processing

Spring Semester 2021

Analysis, synthesis, and application of systems that use coherent or incoherent light.

Topics include:

- Imaging systems (including diffraction effects; incoherent and coherent systems)
- Optical Fourier transforming systems
- Introduction to information processing and computing systems using optics
- Introduction to holography
- Light propagation (exact and approximate)
- Diffraction of light from planar objects, based on scalar diffraction theory
- Coherent and incoherent light (mathematical and physical descriptions)

Sample applications will be selected from these and other topics, and will depend on student interest:

- Computing, including optical memory and interconnections
- Biomedical, including optical coherence tomography for 3-D imaging of human tissue
- Optical metamaterials, negative index of refraction, and superlenses
- 2-D and 3-D displays
- Computational imaging
- Light-field imaging and display
- Noninvasive testing and measurement

Recommended preparation: Continuous-time Fourier transforms, linear systems, and signals/functions.

Time & Location: Tuesday and Thursday 2:00 – 3:20 PM; available online

Text: Joseph W. Goodman, *Introduction to Fourier Optics, Fourth Ed.* (Macmillan Learning, 2017)

Instructor: Prof. B. Keith Jenkins, jenkins@sipi.usc.edu

EE 566 **Optical Information Processing** Spring 2021
B. K. Jenkins **Course Syllabus**
DRAFT V0.95, 1/6/2021

Class days and time: TuTh 2:00 – 3:20 PM. First class on Tuesday 1/19/2021.
Class location: CPA 102 and online*

*Partially in-person instruction will be included only when it is deemed safe and reasonable to do so.

Course preparation

Recommended preparation: Continuous-time Fourier transforms, linear systems, and signals/functions

Required: Graduate standing in engineering or physics.

Relevant but not required: Familiarity with basic electromagnetics.

Course text (required)

Joseph W. Goodman, *Introduction to Fourier Optics*, Fourth Edition (W. H. Freeman and Company, New York, 2017)

Course Web Site and Course Materials

The main web site for all course materials can be accessed from:

blackboard.usc.edu

Course materials (lecture notes, handouts, homework assignments, graded homeworks, etc.) will be available to all registered students at this site. Student work to be graded (e.g., students' solutions to homework assignments) will be uploaded to this site.

Course Contact Information

Instructor: Prof. B. Keith Jenkins
Office: EEB 404A (only when partial in-person instruction is included)
Email: jenkins@sipi.usc.edu [Please include "EE 566" in the subject line]
Office hours: Tu Th 4:00 – 5:00 PM

Grader.: TBD
Email:

Grading (tentative)

Homework	Approximately 1 per week	50%
Quiz 1**	Date TBD (probably Tu 3/16/2021 or Th 3/18/2021)*	25%
Quiz 2**	Tentatively Thursday, 5/6/2021, 2:00–3:30 PM PDT*	25%
Online participation	(good questions or answers on piazza)	bonus points up to 3%

*Online students in vastly different time zones will be accommodated as appropriate; this might imply changing the time of day for the exam for students in nearby time zones also.

**An extended problem set might be given instead of one of the quizzes, depending on student and instructor preference.

Collaboration on assignments in this class

Collaboration on techniques for solving homework assignments is allowed, and can be helpful; however, each student is expected to work out and write up his or her own solution. Use of other solutions to homeworks, or other assignments from any source including other students, before the assignment is turned in, is not permitted. Of course, collaboration on exams is not permitted. Please also see the last two pages of this syllabus for additional policies that apply to all USC classes.

1. Course introduction

- Course logistics and requirements
- Overview of course material and applications

2. Background material and review

- Delta functions
- Linear systems
- Fourier transforms (2-D)
- Space-bandwidth product and local spatial frequency

3. Scalar diffraction theory and wavefront propagation

- Preliminaries (representation, scalar diffraction theory assumptions)
- Wave and Helmholtz equations
- Formulation of optical waves
- Diffraction during propagation - spatial-frequency domain (Angular spectrum of plane waves)
- Definition and modeling of (passive) optical components
- Diffraction during propagation - spatial domain (Monochromatic and nonmonochromatic cases)
- Analysis of optical systems (spatial domain, Fourier domain, hybrid)
- *Evanescent waves and negative index materials (metamaterials)

4. Approximations to diffraction

- Initial approximations (of Rayleigh-Sommerfeld formula)
- Fresnel (near to far field, paraxial)
- Fraunhofer (far field, paraxial)
- *Limited spatial frequency
- Example 1: absorption and phase gratings; diffraction efficiency
- Example 2: photonic interconnections in multichip modules
- *Example 3: diffractive optical elements – computer designed to synthesize arbitrary diffraction patterns

5. Optical Fourier transforming and imaging using thin-lens systems

=> Assume coherent illumination
- Thin lenses
- Fourier transforming
- Imaging
- *Research example: superlenses to exceed the diffraction limit
- General optical system analysis

6. Coherence

- Spatial and temporal coherence
- Coherent and incoherent illumination
- *Biomedical application example: Optical coherence tomography for 3-D imaging

7. Optical imaging systems

- Frequency-domain analysis of generalized imaging systems
- Coherent illumination
- Incoherent illumination
- *Application example: diffraction effects in the eye

8. Information processing: optical/photonic devices and systems

- Coherent processing systems (including frequency domain processing)
- *Wavefront modulation (fixed materials, real-time devices, diffractive optical elements)
- *Early information processing work
- *Incoherent processing systems
- *Incoherent processing application: compressive sensing of images
- *Application examples: Optics in computing systems - memory and interconnections

9. Introduction to holography

- Wavefront recording and reconstruction
- Planar holography (for 3-D reconstruction and general wavefront reconstruction)
- Application example 1: pictorial holography
- *Application example 2: true 3-D displays
- *Computer-generated holography
- *Volume holography

10. *Other topics and applications of interest

Notes:

*Degree of inclusion and emphasis of indicated topics will depend on class interest and available time.

Sample Applications (Past, Current, and Future)

We will choose a few of these to discuss in class

1. Optics and diffraction effects in the eye

- What is actually incident on the retina
- Effects of coherence, pupil size and shape

2. Signal processing and computing

- Special-purpose parallel signal processing
- Optical interconnections
  - Board-to-board, chip-to-chip, within-chip
- Large-scale artificial neural network processing

3. Optical metamaterials

- Index of refraction $n < 1$ and $n < 0$
- Superlenses
- Cloaking devices

4. Biomedical applications

- Optical coherence tomography
  - 3-D imaging of human tissue
- Infrared optical techniques for brain imaging
- Optical tweezers for control of tiny particles in fluids
- Probing of micro-array-experiment data

5. Displays

- 3-D displays based on integral imaging
- True 3-D displays based on holography
- Multiplane displays based on computer holography
- True 3-D displays based on filled volume techniques
- Head-mounted displays for virtual reality and augmented reality

6. Image acquisition

- Camera optics (e.g., in smartphones)
- 3D image acquisition
- Image acquisition for self-driving cars

7. Diffractive optical components and systems

- Diffractive optical elements (DOE's) for generation of arbitrary output intensity or phase patterns
- Holographic optical elements for generation of arbitrary point-spread functions
- Examples

- Diffractive optical concentrators for solar cells
- Free-space or substrate-mode optical interconnections

8. Smart cameras using photonic multichip modules

- Vision in robots
- Autonomous smart cameras
  - For autonomous visual recognition in adverse environments

9. Non-invasive inspection, test, and measurement

- Holographic-interferometric measurement of distances and surface shape variations
- Inspection of integrated circuits after fabrication
- Measurement of surface warping due to stress and strain
  - Mechanical systems in automobiles, aircraft, and spacecraft
  - Optimize strength, durability, weight
- Test of VLSI circuit function using optical access (input and output of test signals)

10. Lidar

- "Light imaging, detection, and ranging"
- Remote sensing of the environment
- Sensing surroundings for autonomous vehicles

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems

Student Health Counseling Services - (213) 740-7711 – 24/7 on call
engemannshc.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 – 24/7 on call
engemannshc.usc.edu/rsvp
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) | Title IX - (213) 740-5086
equity.usc.edu, titleix.usc.edu
Information about how to get help or help a survivor of harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following protected characteristics: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations.

Bias Assessment Response and Support - (213) 740-2421
studentaffairs.usc.edu/bias-assessment-response-support
Avenue to report incidents of bias, hate crimes, and microaggressions for appropriate investigation and response.
The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu

Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710
studentaffairs.usc.edu/ssa
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.