USC Viterbi School of Engineering

Ming Hsieh Department of Electrical Engineering

Course Announcement

EE 566: Optical Information Processing

Fall Semester 2019

Analysis, synthesis, and application of systems that use coherent or incoherent light.
For academic year 2019-2020, this course is offered in the fall.

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: Monday and Wednesday 4:00 – 5:20 PM, KAP 158

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

Instructor: Prof. B. Keith Jenkins, EEB 404A, jenkins@sipi.usc.edu, (213) 740-4149

EE 566 **Optical Information Processing** Fall 2019
B. K. Jenkins **Course Syllabus**
V1.0, 4/4/2019

Class days and time: MW 4:00 – 5:20 PM
Class location: KAP 158

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, etc.) will be available to all registered students at this site.

Course Contact Information

Instructor: Prof. B. Keith Jenkins
Office: EEB 404A
Email: jenkins@sipi.usc.edu [Please include "EE 566" in the subject line]
Phone: 213-740-4149
Fax: 213-740-6618
Office hours: TBD

Grader.: TBD
Email:

Grading

Homework	Approximately 1 per week	20%
Midterm	Wednesday, Oct. 23, 2019, 4:00–5:20 PM PDT	40%
Final exam	Wednesday, Dec. 11, 2019, 4:30–6:30 PM PST	40%

Class participation ("instructor endorsed" posts on piazza online forum) - bonus points up to 3%

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 page 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 domain (Monochromatic and nonmonochromatic cases)
- Diffraction during propagation - spatial-frequency domain (Angular spectrum of plane waves)
- *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
- *Application example of volume holography: diffractive optical concentrators for solar cells

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

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 and aircraft
  - 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 vehicle operation

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" https://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, http://policy.usc.edu/scientific-misconduct.

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

National Suicide Prevention Lifeline - 1-800-273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. http://www.suicidepreventionlifeline.org

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

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: http://sarc.usc.edu/

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. https://equity.usc.edu/

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. https://studentaffairs.usc.edu/bias-assessment-response-support/

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. http://dsp.usc.edu

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

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. https://diversity.usc.edu/

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible, http://emergency.usc.edu

USC Department of Public Safety – 213-740-4321 (UPC) and 323-442-1000 (HSC) for 24-hour emergency assistance or to report a crime.
Provides overall safety to USC community. http://dps.usc.edu