USC Viterbi
School of Engineering

Ming Hsieh
Department of Electrical Engineering

Course Announcement

EE 566: Optical Information Processing

Spring Semester 2014

This course covers the analysis, synthesis, and application of systems that use coherent or incoherent light.

Topics include:

- Scalar diffraction theory
- Diffraction from planar objects; light propagation (exact and approximate)
- Coherent and incoherent light (mathematical and physical descriptions)
- 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

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
- Optical imaging and sensing using compressive sampling
- Noninvasive testing and measurement
- Diffractive optical concentrators for solar cells

Prerequisite:	EE 401 or equivalent knowledge of Fourier transforms and linear systems
Time & Location:	Monday and Wednesday 12:30 - 1:50 PM, OHE 100B; and DEN locations.
Text:	Joseph W. Goodman, *Introduction to Fourier Optics, Third Ed*. (Roberts and Co., Englewood, Colorado, 2005)
Instructor:	Prof. B. Keith Jenkins, EEB 404A, jenkins@sipi.usc.edu, (213) 740-4149

Class days and time: MW 12:30 - 1:50 PM PT
Class location: OHE 100B and on DEN

Course prerequisites

Required: Knowledge of signals, linear systems, and Fourier transforms at the level of EE 301 or EE 401. Graduate standing in engineering or physics.

Relevant but not required: Familiarity with basic electromagnetics.

Course text (required)

Joseph W. Goodman, *Introduction to Fourier Optics*, Third Edition (Roberts & Company, Englewood, Colorado, 2005)

Course Materials (daily lecture notes, handouts, and homeworks)

These materials will be available for downloading from the web. (For daily lecture notes, allow 24 hours after each class for posting.) The web site for EE 401 materials is reachable from your DEN login page:

www.uscden.net

Your DEN account is automatically set up for you if you are registered for this class. You will need Adobe Reader to view the files.

Course Contact Information

Instructor: Prof. B. K. Jenkins
Office: EEB 404A
Phone: 213-740-4149
Fax: 213-740-6618
Email: jenkins@sipi.usc.edu [Please include "EE 566" in the subject line]
Office hours: Tuesday and Thursday, 3:30 – 5:00 PM

Grader.: TBA
Office:
Phone:
Fax:
Email:

Grading

Homework	Approximately 1 per week, mostly to be solved with pen and paper; some optional problems may use applets (to be provided) or a small amount of coding.	20%
Midterm	TBA; will be one of: M 3/3, W 3/5, M 3/10, W 3/12, during 12:30 – 1:50 PM PDT (all are regular class lecture times).	40%
Final exam	Friday, May 9, 2014, 11:00 AM – 1:00 PM PDT.	40%

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. Website and contact information for DSP: http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html, (213) 740-0776 (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX) ability@usc.edu.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. *SCampus*, the Student Guidebook, (www.usc.edu/scampus or http://scampus.usc.edu) contains the University Student Conduct Code (see University Governance, Section 11.00), while the recommended sanctions are located in Appendix A.

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies.

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 formulas
     (Monochromatic and nonmonochromatic cases)
   - Angular spectrum of plane waves interpretation
     (Spatial-frequency domain)
   - *Evanescent waves and negative index materials (metamaterials)
4. Approximations to diffraction formulas
   - Rayleigh-Sommerfeld formula; initial approximations
   - Fresnel (near to far field, paraxial)
   - Fraunhofer (far field, paraxial)
   - *Far-field, large angle
   - Regions of validity
   - *Limited spatial frequency
   - Examples 1: absorption and phase gratings; diffraction efficiency
   - *Examples 2: diffractive optical elements – computer designed to synthesize arbitrary diffraction patterns
5. Optical Fourier transforming and imaging using thin-lens systems
   - => Assume monochromatic 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. Analysis of 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
   - *Wavefront modulation (fixed materials, real-time devices, diffractive optical elements)
   - *Early information processing work
   - *Incoherent processing systems
   - *Incoherent processing application: compressive sensing of images
   - Coherent processing systems (including frequency domain processing)
   - *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: noninvasive evaluation of surface topography
   - *Computer-generated holography
   - *Volume holography
   - *Application example: 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)

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
   - Quantum computing and communication
3. Optical memory
   - Optical disk: CD, DVD
   - 3-D holographic memory
4. Optical metamaterials
   - Index of refraction $n < 1$ and $n < 0$
   - Superlenses
   - Cloaking devices
5. 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
6. Displays
   - 3-D displays based on integral imaging
   - True 3-D displays based on holography
   - True 3-D displays based on filled volume techniques
   - Head-mounted displays for virtual reality and augmented reality
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
     - CD or DVD pickup heads

   - 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
   - Head-mounted smart cameras
     - For location and recognition of objects for augmenting or annotating a real scene

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. Optical imaging and sensing using compressive sampling
    - High quality image acquisition using a lot fewer sampling pixels
    - Remove human from loop (acquired images fed directly to subsequent processing stages)