EE 566 **Optical Information Processing** **Spring 2016**
B. K. Jenkins **Course Syllabus**
v2, 1/9/2016

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

Course preparation

Required: Knowledge of signals, linear systems, and Fourier transforms at the level of EE 301 or higher. 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 Web Site and Course Materials

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

courses.uscden.net

After logging in, in the upper left, next to "My Home", select "EE 566".

Course materials (lecture notes, course notes, handouts, homework assignments, etc.) will be available to all registered students at this site. Live lecture broadcasts and video archives of lectures can also be accessed from this site.

Daily lecture notes (written out in real time during lecture) will be available a few hours after class, at the same web site. Class notes for some lectures will be prepared in advance and will be available on the web site.

Course Contact Information

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Distance Education Network (DEN@Viterbi) students: For help with DEN@Viterbi web site access, transferring of course materials (e.g., turning in and receiving homeworks from remote sites), and viewing downloaded files and viewing video lectures, consult the help function and service/contact info on the DEN web sites:

www.uscden.net and gapp.usc.edu/graduate-programs/den .

Grading

Homework	Approximately 1 per week	20%
Midterm	TBA; during regular class time, sometime during first 2 weeks of March	40%
Final exam	Friday, May 6, 2016, 11:00 AM - 1:00 PM PDT	40%
Class participation (lectures, 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.

Course Overview

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

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)
   - Regions of validity
   - *Far-field, large angle
   - *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 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
   - *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)

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
   - Quantum computing and communication
3. Optical memory
   - Optical disc: CD, DVD, Blue-Ray
   - 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
   - Multiplane displays based on computer holography
   - True 3-D displays based on filled volume techniques
   - Head-mounted displays for virtual reality and augmented reality
7. Image acquisition
   - Camera optics (e.g., in smartphones)
   - 3D image acquisition

8. 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
9. 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
10. 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)
11. 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)

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 Section 11, *Behavior Violating University Standards* https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions. 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.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu or to the *Department of Public Safety* http://capsnet.usc.edu/department/department-public-safety/online-forms/contact-us. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage http://sarc.usc.edu describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* at http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information http://emergency.usc.edu* will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.