Syllabus

Instructor: Randy A. Bartels

Office: 316 Scott Bioengineering Building Engineering

Office Hours: by appointment

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Lecture: TTh, 11:00-12:15 pm: 231 Scott Bioengineering Building

Recitation: M, 1:00-1:50 pm: 231 Scott Bioengineering Building

Texts:

- *Introduction to Optical Microscopy* Jerome Mertz, Cambridge University Press – Second Edition, 2019; ISBN-9781108552660
- *Wavefront Shaping for Biomedical Imaging (Advances in Microscopy and Microanalysis) 1st Edition* Joel Kubby (Editor), Sylvain Gigan (Editor), Meng Cui (Editor) Cambridge University Press; – First Edition, 2019; ISBN-13: 978-1107124127 ISBN-10: 1107124123
- *Introduction to Fourier Optics* J.W. Goodman, Roberts & Company Publishers – Third Edition, 2004; ISBN-13: 978-0974707723
- *Introduction to Modern Optics* Grant R. Fowles Dover – Second Edition, 1975 ISBN – 0-486-65957-7
- *Computational Fourier Optics: A Matlab Tutorial* David Voelz SPIE Press ISBN – 978-0-8194-8204-4

Background: Electromagnetics & Linear Systems Theory

HW Policy: No extensions. Graded only if *legible* (as judged by grader).

Course Description: This course will serve as an introduction to the concepts of optical systems and imaging from a linear systems wave perspective. We will cover the topics listed below with a major emphasis on Fourier Optics and the description of optical imaging systems. Upon completion of this course, students should be able to design and analyze a simple optical system.

Homework: The homework is an essential part of the course. You should attempt all problems yourself, but feel free to argue with your colleagues about them. (Simply copying each other's solutions is, however, counterproductive for all parties and is not acceptable.) Homework will be due on the Friday one week after it is assigned at the beginning of class.

A homework solution MUST include a full explanation of how the problem is set up, the motivation of steps in the analysis, and an interpretation of the results. The entire point of homework is to explore and think about the material presented in the class AND to be able to communicate your findings. The ability to communicate scientific ideas is of critical importance. Moreover, the emphasis of homework is to analyze each physical situation, interpret that analysis, and communicate the meaning. As a result, the emphasis is NOT on algebraic manipulations. You are encouraged to use Mathematica (and to a MUCH lesser extent other mathematical tools) to write up your solution. All solutions MUST be in a highly simplified form that YOU interpret correctly. Remember: each homework solution should be a short story that includes a reproduction of appropriate diagrams and may require plots of the final solutions you find to explain behaviors.

Late homework will not be accepted.

Numerical Projects: We will have a series of numerical projects to be implemented in Matlab or Mathematica. The early assignments are designed to build the necessary Matlab and Mathematica skill set required for realistic simulations of light propagation with the Fourier optics tools that we learn in the class.

Topics and Schedule:

1. A review:
   Linear Systems Theory
   Fourier Transforms and their physical meaning
   A brief optics refresher
2. Principles of Wave Optics
   Wave theory
   Optical components from the viewpoint of wave optics
   Interference
3. Fourier Transforms in Optics
4. Diffraction Theory
   Fresnel and Fraunhofer diffraction
   Applications of diffraction

5. Optical Systems
   Lens Theory
   Coherent and incoherent systems
   Frequency response of optical systems

Recitation Topics:

1. Models of optical imaging systems and diffraction
2. A brief introduction to inverse problems and noise
3. **Imaging with diffraction:**
   Iterative Phase Retrieval
   Transport of Intensity
   Holography
   Diffraction Tomography
4. **Deconvolution and Projection Optical Tomographic Microscopy:**
   Fluorescent Deconvolution and Tomography
   Coherent Imaging Deconvolution
   Interferometric Synthetic Aperture Microscopy
   Imaging the complex transmission matrices
5. **Single Pixel Microscopy:**
   Confocal and Nonlinear Microscopy
   Ghost Imaging
   Hadamard Transform Optics
   Spatial Frequency Projection Imaging
   Compressed Sensing
6. **Structured Illumination Microscopy:**
   Structured illumination for axial sectioning
   Structured Illumination for SuperResolution
   Dynamic Speckle Imaging
   HiLo Imaging
   Imaging with Unknown Speckle Patterns
7. **Localization Microscopy:**
   Estimating the position of emitters
   Super Resolution with Localization

Grading and Exams:

Homework	**25%**		**100.00-90.00%**	**A**
Numerical Projects	**25%**		**89.99-79.00%**	**B**
Exams	**50%**		**78.99-68.00%**	**C**
			67.99-57.00%	**D**
			Below 56.99%	**F**