ECE 792-064
Radiometry, Diffraction, and Polarized Light

Instructor(s): Michael Kudenov (mwkudeno@ncsu.edu)

Objective or Description:

This course will cover three critical aspects of optics in three sections:

(1) Radiometry and Remote Sensing. This module will cover radiometric transfer, starting with the throughput equation, transmission through media (glass, atmosphere), diffuse and specular reflectance modeling, source characteristics (brightness, divergence), propagation of radiation from several viewpoints (normalized solid angle, normalized area), blackbody radiation (Plank's law) and associated modeling. Additionally, noise sources in radiometry will be covered in detail, including Johnson, Shot, and Photon noise. A major project will include the design and optimization of a satellite-based remote imaging system, which will require students to design a radiometric transfer model that describes the major system losses, and to address the areas of the system that can be modified to improve the signal-to-noise ratio.

(2) Polarized Light. An overview of polarization theory for applications in light-matter interactions, lithography, device fabrication, optical testing, spectroscopy, and interferometry will comprise the next module. We will start with an introduction to the basic polarization theories of Jones matrices. Investigations will include the action of optical devices, including polarizers, waveplates, modulators (uniaxial crystals), total internal reflection, and Fresnel reflection and refraction, which can be modeled with the Jones matrix formalism. This will set the framework for the second part of the course that will address Stokes and Mueller polarimetry theory. From here, the concept of the Poincare sphere will be introduced in detail, including the action of retardance, depolarization, and diattenuation. Lastly, we will detail how the Mueller matrix formalism can be leveraged to calibrate polarization sensors, and how polarized light is quantified within a laboratory or experimental environment. This will include discussing applications, including ellipsometry, polarized remote sensing, and imaging polarimetry.

(3) Diffraction. While geometrical optics implies that perfect imaging can occur (e.g., rays can focus to an infinitely small "singularity"), this is not a realistic model; rather, it is a first-order approximation. Thus, treating light propagation from a wavefront standpoint lends itself to a higher-order approximation, which is commonly referred to as Fourier optics or scalar diffraction theory. This theory states that a focus of rays can not create a singularity, but has some dimensional constraints. Through this module, we will see that the concept of diffraction can be related to interferometry, the limitations of which create the basis for many of the limitations in current high-tech photolithography systems.

Prerequisites: ECE 523, Physics 516, or MAE 589-004, or prior graduate course in introductory optics.

Textbook:
Linear Systems, Fourier Transforms, and Optics - *J. Gaskill*
Edition: 1st
ISBN: 978-0471292883
Web Link: http://catalog.lib.ncsu.edu/record/NCSU456510
Cost: 170
This textbook is optional.
The Art of Radiometry - *Palmer*
Edition: 1st
Web Link: http://spie.org/Publications/Book/798237
Cost: 92
This textbook is optional.
Polarized Light and Optical Systems - *Russell Chipman*
Edition: 1st
Web Link: https://www.amazon.com/Polarized-Optical-Systems-Sciences-Applications/dp/149870056X/ref=sr_1_2?crid=1VMXV6AIZS198&keywords=Polarized+light+chipman&qid=1680552752&sprefix=polarized+light+chipman%2Caps%2C90&sr=8-2

Cost: 160
This textbook is optional.

Topics:

At the end of this course, students should be able to:

1) Setup a radiometric transfer problem, based on source power, detector sensitivity, propagation distance, and surface reflectance and geometry.

2) Solve associated radiometric transfer problems, and optimize them for maximum radiometric throughput.

3) Calculate signal to noise ratios, based on the optical transfer chain.

4) Describe tradeoffs to various remote sensing problems, including but not limited to image blur, integration time, source brightness, and source distance.

5) Calculate the scalar diffraction intensity distribution of a light field behind a series of apertures and optical surfaces.

6) Apply Fourier transformations or Fourier relationships to derive the far field intensity distribution of a light field.

7) Interpret, in their own words, how the phase of the light field changes vs propagation distance and how this influences the measured intensity.

8) Model polarization interactions using the Jones, Stokes, and Mueller formalisms.

9) Visualize Stokes and Mueller matrices on the Poinicare sphere and use this to describe the action of linear polarizers and retarders.

10) Describe how the different components of a Mueller matrix contribute to depolarization, retardation, and diattenuation.

11) Apply the Mueller and Stokes formalism to calibrate polarization sensors through data reduction matrices and Harmonic analysis.

12) Describe, in their own words, optimal polarization references in the laboratory and why they are often used (e.g., total internal reflection, Fresnel reflections, etc.)

Grading:

Grade Components

Component	Weight	Details
Homework / Projects	60	Homeworks and project assignments will be assigned each week and due the subsequent week at the beginning of class.
Midterm 1	20	
Final Exam / Final Midterm	20	