Opti 537, Imaging Physics and Devices
Syllabus, Fall 2023

This course presents a synthesis of the essential physics needed to mathematically describe imaging, from creation of light that will illuminate a scene through detection and signal generation in a modern imaging sensor. The course is organized into 5 key topic areas:

Unit I: Sources of light and other radiation

- Introduction to electromagnetic radiation; accelerated charges
- Wave equations and Green's functions
- Dipole radiation, antennas, phased arrays
- Synchrotrons, x-ray sources, free-electron lasers

Unit II: Propagation of radiant energy

- Review of diffraction theory
- Fresnel and Fraunhofer diffraction
- Effect of lenses; coherent and incoherent imaging
- Introduction to radiometry
- Radiative transport
- Solutions of the transport equation, relation to imaging

Unit III: Interaction of radiation and matter

- DeBroglie waves, origins of quantum mechanics
- Time-dependent and time-independent Schrodinger equations and their interpretation
- Hilbert space, bras and kets
- Quantum states of isolated atoms, transitions, selection rules
- Two-level atoms, Rabi flopping, rate equations
- Fermi's Golden rule
- Photoelectric effect
- Compton scatter and pair production

Unit IV: Semiconductor physics and devices

- Crystalline and non-crystalline solids
- Energy bands, effective mass, Fermi level
- Mobility and conductivity
- Photoconductivity and photoconductive detectors
- Doping, P-N junctions
- Photoelectric detectors, avalanche photodiodes
- Detector arrays; CCD and CMOS devices
- Light-emitting diodes and semiconductor lasers
- Other solid-state devices

Unit V: Photoelectronic imaging devices

- Photocathodes and photomultipliers
- Image intensifiers, position-sensitive detectors

Learning objectives:

Upon completion of this course, students will

- be able to articulate the origins, assumptions, and/or boundary conditions that are invoked in the derivations of the essential physical equations that describe imaging;
- have gained experience in solving qualitative and quantitative problems in imaging physics using theory and simulations at a variety of levels of approximation; and
- be able to describe the fundamental principles of a broad selection of devices involved in the creation, propagation, and detection of light.