OPTI414/514 Optical Instrumentation

This course will introduce students to the principles, designs, applications, and recent developments of a broad variety of optical instruments. Upon completion of the course students will be able to understand optical principles, design requirements, and how to apply these instruments in practices.

Prerequisite: OPTI 340

Grading:
OPTI414 (undergraduate):
Homework 40%
Midterm 30%
Course project 30%

OPTI514 (graduate)
Homework 25%
Midterm 25%
Course project 25%
Presentation 25%

Course Outline
1. Eye
   1.1 Human eye
      1.1.1 Human structure and properties
      1.1.2 Schematic eye
      1.1.3 Human eye inspired optics
   1.2 Animal eye
      1.2.1 Animal eye structure and properties
      1.2.2 Animal eye inspired optics

2. Introduction to microscopy
   2.1 Fundamentals
   2.2 Objectives
      2.2.1 Types of objectives
      2.2.2 Design principles
   2.3 Reflective objectives
   2.4 Tube lens
   2.5 Illumination
      2.5.1 Critical illumination
      2.5.2 Kohler illumination
      2.5.3 Dark field illumination
   2.6 Stereo microscopes
      2.6.1 Design considerations
      2.6.2 Applications
   2.7 Eyepieces
      2.7.1 Types of eyepieces
      2.7.2 Design principles

3. Advanced microscopy
   3.1 Phase contrast microscope
      3.1.1 Principle
      3.1.2 Applications
   3.2 Differential interference contrast microscope
      3.2.1 Principle
      3.2.2 Applications
3.3 Polarization microscope
   3.3.1 Principle
   3.3.2 Polarization imaging systems
   3.3.3 Design considerations
      3.3.3.1 Configurations
      3.3.3.2 Components
      3.3.3.3 Optical materials
      3.3.3.4 System analysis
   3.3.4 Applications
4. Fluorescence imaging systems
   4.1 Fluorescence microscope
      4.1.1 Principle
         4.1.1.1 Fundamentals of fluorescence
         4.1.1.2 Fluorescence filters
         4.1.1.3 System configuration
      4.1.2 Multiphoton microscope
      4.1.3 Total internal reflection fluorescence (TIFF) microscopy
      4.1.4 Fluorescence lifetime imaging microscopy (FLIM)
   4.2 Fluorescence imaging systems
      4.2.1 Configurations
      4.2.2 Design considerations
      4.2.3 Applications
5. Telescopes
   5.1 Fundamentals
   5.2 Refracting telescopes
   5.3 Reflecting telescopes
      5.3.1 Configurations
      5.3.2 Field correctors
      5.3.3 Focal reducer/extenders
      5.3.4 Aperture obscuration
      5.3.5 Design considerations
   5.4 Tilted-component telescopes
      5.4.1 Configurations
      5.4.2 Three-mirror Anastigmats
   5.5 Large telescopes
6. Photographic systems
   6.1 History
   6.2 Film and image sensor
   6.3 Photographic lenses
      6.3.1 Landscape lens
      6.3.2 Petzval lens
      6.3.3 Cooke triplet and Tessar lenses
      6.3.4 Retrofocus and telephoto lenses
      6.3.5 Double-Gauss lens
      6.3.6 Wide angle lenses
   6.4 Zoom lenses
   6.5 Digital camera
   6.6 Phone camera
   6.7 Image stabilization
   6.8 Special aspects of photographic lenses
   6.9 New development
7. Displays
   7.1 History
   7.2 Projection displays
      7.2.1 Principle
         7.2.1.1 Light valves
         7.2.1.2 Configurations
         7.2.1.3 Illumination systems
      7.2.2 DMD projection display
      7.2.3 LCD projection display
      7.2.4 LCoS projection display
   7.3 Pico projector
   7.4 Flat panel displays
      7.4.1 Optical films
      7.4.2 Light guide plate
   7.5 Digital cinema
   7.6 3D display
      7.6.1 3D display with viewing aids
      7.6.2 Autostereoscopic displays
8. Spectral imaging systems
   8.1 Fundamentals
   8.2 Spectral imaging systems
   8.3 Optical configurations
      8.3.1 Raster scanning
      8.3.2 Line scanning
      8.3.3 Band-sequential imaging
      8.3.4 Band-simultaneous imaging
      8.3.5 Fully simultaneous imaging
   8.4 Design considerations
   8.5 Applications
9. Optical Coherence Tomography (OCT)
   9.1 Low coherence interferometry
   9.2 Optical coherence tomography
      9.2.1 Principle
      9.2.2 Time-domain OCT
         9.2.2.1 Optical delay lines
         9.2.2.2 Scanning optics
      9.2.3 Fourier-domain OCT (FD-OCT)
         9.2.3.1 Spectral-domain OCT (SD-OCT)
         9.2.3.2 Swept source OCT (SS-OCT)
   9.3 Ultra-high resolution OCT
   9.4 Multimodal OCT
   9.5 Applications
10. Confocal system
    10.1 Introduction
    10.2 Basic components and requirements
    10.3 Confocal scanning systems
       10.3.1 Scanning systems
       10.3.2 Relay optics
    10.4 Optical design of the objective lenses
    10.5 Fiber-optic confocal imaging systems
       10.5.1 Single fiber confocal system
       10.5.2 Fiber bundle confocal system
11. Endoscopy
   11.1 Introduction
   11.2 Basic optics for endoscopes
   11.3 Relay lenses
   11.4 Objective lenses
   11.5 Illuminations
   11.6 Wireless endoscopes
      11.6.1 Objective lens
      11.6.2 Illumination

12. Infrared systems
   12.1 Introduction
      12.1.1 Special aspects of infrared imaging
      12.1.2 Radiation and emissivity
      12.1.3 Atmospheric transmittance
   12.2 Infrared materials
   12.3 Infrared detectors
   12.4 Infrared imaging systems
   12.5 Optical design for infrared systems
   12.6 Athermalization
   12.7 Narcissus

13. Lithographic systems
   13.1 Introduction
   13.2 Physical optics aspects
   13.3 Performance of lithographic lenses
   13.4 Evolution of lithographic lens systems
      13.4.1 Aspherical systems
      13.4.2 Immersion systems
      13.4.3 Catadioptric systems
      13.4.4 Mirror systems
   13.5 Optical design for lithographic systems

Textbook:
No textbook required

Grading Scale:
85-100%: A
75-85%: B
65-75%: C
50-65%: D
<50%: E

Homework Policy:
Regular homework assignments will be given one week before the due date. All homework is due at the beginning of class on the due date. Late homework will receive up to 50% deduction.