J. C. Wyant
Fall, 2011

# Optics 513 - Optical Testing and Testing Instrumentation

**Term:** Fall 2011

**Instructor:** James C. Wyant
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**Office Hours:** Call for appointment or see after class

**Course Time on Campus:** Tuesday/Thursday 8:00 - 9:15 AM

**Classroom:** Meinel 305

**Prerequisites:** Optics 505

**Course Description:**

Paraxial properties of optical systems, material qualification, ellipsometry, aberrations, basic interferometers, direct-phase measurement interferometry, measurement of surface quality, testing mirrors, windows, prisms, and corner cubes, measurement of index inhomogeneity, testing of spherical surfaces and lenses, aspheric testing, absolute measurements, and system evaluation.

**Learning Outcomes:**

- Better specify optical components and systems
- Produce higher-quality optical systems
- Determine if an optics supplier can actually supply the optics you are ordering
- Test optical components and systems
- Evaluate optical system performance
- Explain basic interferometry and interferometers for optical testing

Attached you will find a tentative outline and schedule. You will be given a mid-term exam during the semester, plus a final exam. All exams will be in-class, closed book exams. The homework will be due at the beginning of the class on the date stated on each assignment sheet. Unless special permission is given to hand in homework late, credit will be reduced 25% for each day a homework assignment is late. The final grade in the course will be calculated as follows: homework - 20%; mid-term exam - 30%; and final exam - 50%.

## Academic Integrity

According to the Arizona Code of Academic Integrity
(http://deanofstudents.arizona.edu/aboutdeanofstudents),
"Integrity is expected of every student in all academic work. The guiding principle of academic integrity is that a student's submitted work must be the student's own." Unless otherwise noted by the instructor, work for all assignments in this course must be conducted independently by each student. CO-AUTHORED WORK OF ANY KIND IS UNACCEPTABLE. Misappropriation of exams before or after they are given will be considered academics misconduct.

Misconduct of any kind will be prosecuted and may result in any or all of the following:
* Reduction of grade
* Failing grade
* Referral to the Dean of Students for consideration of additional penalty, i.e. notation on a student's transcript re. academic integrity violation, etc.

## Students with a Learning Disability

If a student is registered with the Disability Resource Center, he/she must submit appropriate documentation to the instructor if he/she is requesting reasonable accommodations. (http://drc.arizona.edu/learn/test-accommodation.html).

The information contained in this syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor.

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Introduction

1. Measurement of Paraxial Properties of Optical Systems
   - 1.1 Thin Lenses
     - 1.1.1 Measurements Based on Image Equation
     - 1.1.2 Autocollimation Technique
     - 1.1.3 Geneva Gauge
     - 1.1.4 Neutralization Test
     - 1.1.5 Focometer
   - 1.2 Thick Lenses
     - 1.2.1 Focal Collimator
     - 1.2.2 Reciprocal Magnification
     - 1.2.3 Nodal-Slide Lens Bench

2. Qualification of Optical Material
   - 2.1 Internal Defects
   - 2.2 Measurement of Refractive Index
     - 2.2.1 Spectrometer
       - 2.2.1.1 Basic Spectrometer Technique
       - 2.2.1.2 Autocollimating Goniometer
       - 2.2.1.3 Hilger Chance Refractometer
     - 2.2.2 Critical Angle Systems
       - 2.2.2.1 Abbe Refractometer
       - 2.2.2.2 Pulfrich Refractometer
     - 2.2.3 Ellipsometry
   - 2.3 Strain
   - 2.4 Mechanical and Thermal Properties

3. Aberrations
   - 3.1 Sign Conventions
   - 3.2 Aberration Free Image
   - 3.3 Spherical Wavefront, Defocus, and Lateral Shift
   - 3.4 Angular, Transverse, and Longitudinal Aberration
   - 3.5 Seidel Aberrations
     - 3.5.1 Spherical Aberration
     - 3.5.2 Coma
     - 3.5.3 Astigmatism
     - 3.5.4 Field Curvature
     - 3.5.5 Distortion
   - 3.6 Zernike Polynomials
   - 3.7 Relationship between Zernike Polynomials and Third-Order Aberrations

- 3.8 Peak-Valley and RMS Wavefront Aberration
- 3.9 Strehl Ratio
- 3.10 Chromatic Aberrations
- 3.11 Aberrations Introduced by Plane Parallel Plates
- 3.12 Aberrations of Simple Thin Lenses
- 3.13 Conics
  - 3.13.1 Basic Properties
  - 3.13.2 Spherical Aberration
  - 3.13.3 Coma
  - 3.13.4 Astigmatism
- 3.14 General Aspheres

4. Basic Interferometry and Optical Testing
   - 4.1 Two Beam Interference
   - 4.2 Fizeau Interferometer
   - 4.3 Twyman-Green Interferometer
   - 4.4 Laser Based Fizeau
   - 4.5 Mach-Zehnder Interferometer
   - 4.6 Typical Interferograms
   - 4.7 Interferograms and Moiré Patterns
   - 4.8 Classical techniques for inputting data into computer

5. Direct Phase Measurement Interferometry
   - 5.1 Introduction
   - 5.2 Zero-Crossing Technique
   - 5.3 Phase-Lock Interferometry
   - 5.4 Up-Down Counters
   - 5.5 Phase-Stepping and Phase-Shifting Interferometry
     - 5.5.1 Introduction
     - 5.5.2 Phase Shifters
     - 5.5.3 Moving Mirror
     - 5.5.4 Diffraction Grating
       - 5.5.4.1 Bragg Cell
       - 5.5.4.2 Polarization Phase Shifters
         - 5.5.4.2.1 Rotating half-wave plate
         - 5.5.4.2.2 Rotating polarizer
       - 5.5.4.3 Zeeman Laser
       - 5.5.4.4 Frequency Shifting Source
     - 5.5.5 Algorithms
     - 5.5.6 Phase-Unwrapping
     - 5.5.7 Phase Shifter Calibration
     - 5.5.8 Errors
     - 5.5.9 Solving the Vibration Problem
       - 5.5.9.1 Measure vibration and introduce vibration 180 degrees out of phase to cancel vibration
       - 5.5.9.2 Spatial Synchronous and Fourier Methods

5.5.9.3 Spatial Carrier Technique
5.5.9.4 Simultaneous Phase-Measurement Interferometer
5.5.9.5 Single-Shot Holographic Polarization Dynamic Interferometer
5.5.9.6 Pixelated Polarizer Array Dynamic Interferometer
5.6 Phase-Shifting Non-Destructive Testing
5.7 Multiple Wavelength and White Light Phase-Shifting Interferometry
5.8 Vertical Scanning (Coherence Probe) Techniques

6. Measurement of Surface Quality
6.1 View transmitted or reflected light
6.2 Mechanical Probe
6.3 AFM
6.4 Lyot Test
6.5 FECO
6.6 Nomarski Interferometer
6.7 Sommargren Profiler
6.8 Interference Microscope

7. Testing Flat Surface Optical Components
7.1 Mirrors
7.1.1 Fizeau Interferometer
7.1.2 Twyman-Green Interferometer
7.1.3 Ritchey-Common Test
7.1.4 Naked Eye Test
7.2 Windows
7.2.1 Interferometer
7.2.2 Autocollimator
7.3 Prisms
7.3.1 Interferometer
7.3.2 Goniometer
7.3.3 Autocollimator
7.3.4 Naked Eye Tests
7.4 Corner Cubes
7.5 Diffraction Gratings
7.6 Index inhomogeneity

8. Testing of Curved Surfaces and/or Lenses
8.1 Radius of Curvature
8.1.1 Spherometer
8.1.2 Autostigmatic Measurement
8.1.3 Newton's Rings
8.1.4 Interferometer and Radius Slide
8.2 Surface Figure
8.2.1 Test Plate
8.2.2 Twyman-Green Interferometer (LUPI)

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# Optics 513 - Optical Testing and Testing Instrumentation, Tentative Schedule

| Lecture No. | Date | Section Covered | Homework due |
|---|---|---|---|
| 1 | Aug. 23 (Tu) | 1.1 - 1.2 | |
| 2 | Aug. 25 (Th) | 2.1 - 2.2 | |
| 3 | Aug. 30 (Tu) | 2.2 – 2.3 | |
| 4 | Sept. 1 (Th) | 2.3 – 3.1 | PP-1, PP-4, OM-5, OM-9 |
| 5 | Sept. 6 (Tu) | 3.2 - 3.4 | |
| 6 | Sept. 08 (Th) | 3.5 - 3.8 | |
| 7 | Sept. 13 (Tu) | 3.9 - 3.14 | A-1, A-3, A-9, A-15 |
| 8 | Sept. 15 (Th) | 4.1 - 4.3 | |
| 9 | Sept. 20 (Tu) | 4.4 - 4.6 | |
| 10 | Sept. 22 (Th) | 4.7 - 4.8 | OT-2, OT-4, OT-6, OT-12 |
| 11 | Sept. 27 (Tu) | 5.1 - 5.4 | |
| 12 | Sept. 29 (Th) | 5.5 | |
| 13 | Oct. 4 (Tu) | 5.6 - 5.7 | DP-1, DP-6, DP-10, DP-16 |
| 14 | Oct. 6 (Th) | 5.8 | |
| 15 | Oct. 11 (Tu) | 6.1 - 6.4 | |
| 16 | Oct. 13 (Th) | 6.5 - 6.8 | |
| 17 | Oct. 18 (Tu) | Exam | Sections 1-5 |
| 18 | Oct. 20 (Th) | 7.0 - 7.1 | SQ-1, SQ-2, SQ-3, SQ-4 |

| Lecture No. | Date | Section Covered | Homework due Covering Section |
|---|---|---|---|
| 19 | Oct. 25 (Tu) | 7.2 - 7.4 | |
| 20 | Oct. 27 (Th) | 7.5 - 7.6 | |
| 21 | Nov. 1 (Tu) | 8.1 - 8.2.3 | FS-1, FS-6, FS-9, FS-12 |
| 22 | Nov. 3 (Th) | 8.2.4 - 8.2.9 | |
| 21 | Nov. 8 (Tu) | 8.2.10 - 8.2.13 | CS-2, CS-6, CS-13 |
| 23 | Nov. 10 (Th) | 8.2.14 - 8.2.15 | |
| 24 | Nov. 15 (Tu) | 8.2.16 - 8.2.17 | |
| 25 | Nov. 17 (Th) | 9.1 - 9.2 | CS-15, CS-24, CS-25 |
| 26 | Nov. 22 (Tu) | 9.3.1 - 9.3.5 | |
| 27 | Nov. 29 (Tu) | 9.3.6 - 9.3.8 | AS-1, AS-4 |
| 28 | Dec. 1 (Th) | 10.1 - 10.3 | |
| 29 | Dec. 6 (Tu) | 11.1 - 11.5 | AS-8, AS-10, SE-3, SE-4 |

Final Exam, TBD.

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# References for Optics 513 - Optical Testing and Testing Instrumentation

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|---|---|
| D. Malacara, Ed. | Optical Shop Testing, Third Edition |
| E. P. Goodwin and J. C. Wyant | Field Guide to Interferometric Optical Testing |
| W. Smith | Modern Optical Engineering |
| Kingslake, Thompson, Shannon, and Wyant, Ed. | Applied Optics and Optical Engineering, Vols. 1-11 |
| B. K. Johnson | Optics and Optical Instruments |
| P. Hariharan | Optical Interferometry, Second Edition |
| D. Malacara, M. Servin, and Z. Malacara | Interferogram Analysis for Optical Testing |
| Optical Society of America | Optics Infobase |
| SPIE | Digital Library |