

Optics 513 - Optical Testing and Testing Instrumentation

Term: Fall 2013

Instructor: James C. Wyant
Meinel Building Rm 652
University of Arizona
Tucson, AZ 85721

E-Mail: jcwyant@optics.arizona.edu

Website: www.optics.arizona.edu/jcwyant

Office Hours: Email for appointment

Course Time: Recorded Lectures to be viewed on student's computer on days given on class schedule

Classroom for exams: 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 by 12:00 noon on the date stated on each assignment sheet and it should be handed in to Susan Nares in room 642. 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.

Optics 513 - Optical Testing and Testing Instrumentation

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 Pioneer Fizeau Interferometer
 - 4.3 Twyman-Green Interferometer
 - 4.4 Fizeau Interferometer – Laser Source
 - 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
 - 5.5.2.1 Moving Mirror
 - 5.5.2.2 Diffraction Grating
 - 5.5.2.3 Bragg Cell
 - 5.5.2.4 Polarization Phase Shifters
 - 5.5.2.4.1 Rotating Half-Wave Plate
 - 5.5.2.4.2 Rotating polarizer in Circularly Polarized Beam
 - 5.5.2.5 Zeeman Laser
 - 5.5.2.6 Frequency Shifting Source
 - 5.5.3 Algorithms
 - 5.5.4 Phase-Unwrapping
 - 5.5.5 Phase Shifter Calibration
 - 5.5.6 Errors
 - 5.5.6.1 Error Due to Stray Reflections
 - 5.5.6.2 Quantization Error
 - 5.5.6.3 Detector Nonlinearity
 - 5.5.6.4 Source Instabilities
 - 5.5.6.5 Error Due to Incorrect Phase-Shift Between Data Frames

- 5.5.7 Solving the Vibration Problem
 - 5.5.7.1 2 + 1 Algorithm
 - 5.5.7.2 Measure vibration and introduce vibration 180 degrees out of phase to cancel vibration
 - 5.5.7.3 Spatial Synchronous and Fourier Methods
 - 5.5.7.4 Spatial Carrier Technique
 - 5.5.7.5 Simultaneous Phase-Measurement Interferometer
 - 5.5.7.6 Single-Shot Holographic Polarization Dynamic Interferometer
 - 5.5.7.7 Pixelated Polarizer Array Dynamic Interferometer
- 5.6 Phase-Shifting Nondestructive 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 – Stylus Profilometry
 - 6.3 AFM– Atomic Force Microscope or SPM – Scanning Probe Microscope
 - 6.4 Lyot Test (Zernike Phase Contrast)
 - 6.5 FECO – Fringes of Equal Chromatic Order
 - 6.6 Nomarski Interferometer - Differential Interference Contrast (DIC)
 - 6.7 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

- 8.2 Surface Figure
 - 8.2.1 Test Plate
 - 8.2.2 Twyman-Green Interferometer (LUPI)
 - 8.2.3 Fizeau Interferometer (Laser source)
 - 8.2.4 Spherical Wave Multiple Beam Interferometer (SWIM)
 - 8.2.5 Shack Cube Interferometer
 - 8.2.6 Scatterplate Interferometer
 - 8.2.7 Smartt Point Diffraction Interferometer
 - 8.2.8 Sommargren Diffraction Interferometer
 - 8.2.9 Measurement of Cylindrical Surfaces
 - 8.2.10 Long-Wavelength Interferometry
 - 8.2.11 Star Test
 - 8.2.12 Shack-Hartmann Test
 - 8.2.13 Foucault Knife-Edge Test
 - 8.2.14 Wire Test
 - 8.2.15 Ronchi Test
 - 8.2.16 Lateral Shear Interferometry
 - 8.2.17 Radial Shear Interferometry

- 9. Special Interferometric Tests for Aspherical Surfaces
 - 9.1 Aspheric Surfaces
 - 9.1.1 Conics
 - 9.1.2 Sag for Aspheres
 - 9.2 Null Test
 - 9.2.1 Conventional Null Optics
 - 9.2.2 Holographic Null Optics
 - 9.2.3 Computer Generated Holograms
 - 9.3 Non-Null Test
 - 9.3.1 SCOTS
 - 9.3.2 Scanning Pentaprism Test
 - 9.3.3 Lateral Shear Interferometry
 - 9.3.4 Radial Shear Interferometry
 - 9.3.5 High-Density Detector Arrays
 - 9.3.6 Sub-Nyquist Interferometry
 - 9.3.7 Long-Wavelength Interferometry
 - 9.3.8 Two-Wavelength Holography
 - 9.3.9 Two-Wavelength Interferometry
 - 9.3.10 Moiré Interferometry (Projected Fringes)
 - 9.3.11 Stitching Interferograms

- 10. Absolute Measurements
 - 10.1 Flat Surfaces
 - 10.2 Spherical Surfaces
 - 10.2.1 Three Measurements of Spherical Mirror
 - 10.2.2 Ball Averager
 - 10.3 Surface Roughness

- 10.3.1 Perfect Mirror
- 10.3.2 Generate Reference
- 10.3.3 Absolute rms Measurement

- 11. System Evaluation
 - 11.1 Resolution Tests
 - 11.2 Veiling Glare
 - 11.3 Spread Function Measurement
 - 11.4 Encircled Energy Measurement
 - 11.5 Optical Transfer Function Measurement
 - 11.5.1 Scanning Methods
 - 11.5.2 Interferogram Analysis
 - 11.5.3 Autocorrelation Method

Optics 513 - Optical Testing and Testing Instrumentation, Tentative Schedule

<u>Lecture No.</u>	<u>Date</u>	<u>Section Covered</u>	<u>Homework due</u>
1	Aug. 27 (Tu)	1.1 - 1.2	
2	Aug. 29 (Th)	2.1 - 2.2	
3	Sept. 03 (Tu)	2.2 - 2.3	
4	Sept. 05 (Th)	2.3 - 3.1	PP-1, PP-4, OM-5, OM-9
5	Sept. 10 (Tu)	3.2 - 3.4	
6	Sept. 12 (Th)	3.5 - 3.8	
7	Sept. 17 (Tu)	3.9 - 3.14	A-1, A-3, A-9, A-15
8	Sept. 19 (Th)	4.1 - 4.3	
9	Sept. 24 (Tu)	4.4 - 4.6	
10	Sept. 26 (Th)	4.7 - 4.8	OT-2, OT-4, OT-6, OT-12
11	Oct. 01 (Tu)	5.1 - 5.4	
12	Oct. 03 (Th)	5.5	
13	Oct. 08 (Tu)	5.6 - 5.7	DP-1, DP-6, DP-10, DP-16
14	Oct. 10 (Th)	5.8	
15	Oct. 15 (Tu)	6.1 - 6.4	
16	Oct. 17 (Th)	6.5 - 6.7	
17	Oct. 22 (Tu)	Exam (8:00 - 9:15 AM)	Sections 1-5
18	Oct. 24 (Th)	7.0 - 7.1	SQ-1, SQ-2, SQ-3, SQ-4

<u>Lecture No.</u>	<u>Date</u>	<u>Section Covered</u>	<u>Homework due Covering Section</u>
19	Oct. 29 (Tu)	7.2 - 7.4	
20	Oct. 31 (Th)	7.5 - 7.6	
21	Nov. 05 (Tu)	8.1 - 8.2.3	FS-1, FS-6, FS-9, FS-12
22	Nov. 07 (Th)	8.2.4 - 8.2.9	
23	Nov. 12 (Tu)	8.2.10 - 8.2.13	CS-2, CS-6, CS-13
24	Nov. 14 (Th)	8.2.14 - 8.2.15	
25	Nov. 19 (Tu)	8.2.16 - 8.2.17	
26	Nov. 21 (Th)	9.1 - 9.2	CS-15, CS-24, CS-25
27	Nov. 26 (Tu)	9.3.1 - 9.3.5	
28	Dec. 03 (Tu)	9.3.6 - 9.3.11	AS-1, AS-4
29	Dec. 05 (Th)	10.1 - 10.3	
30	Dec. 10 (Tu)	11.1 - 11.5.3	AS-8, AS-10, SE-3, SE-4

Final Exam: Dec. 19, 8:00 AM – 10:00 AM in Meinel 305.

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 |