Optics 505 – Diffraction and Interferometry

Term: Spring 2025

Course #: OPTI 505R

Course Title: Diffraction and Interferometry

Instructor: Tom D Milster

Email: milster@optics.arizona.edu

Web site: www.d2l.arizona.edu

Office Hours: Office hours and Zoom links are posted on D2L

Course Time: 9:30 – 10:45 AM
Dates: Tuesday/Thursday
Location: Meinel 307

Prerequisites: Optics (501), 512

TA: Zichan Wang (wangzichan@arizona.edu)
Office hours and Zoom links are posted on D2L

Course Description:

Waves and Polarization, Interference and interferometry; diffraction theory; Fraunhofer and Fresnel diffraction; concepts of coherence; optical transfer function (Holography and Speckle are presented in optional lectures).

Homework, Grades, and Exams/Final

There is a midterm exam and a comprehensive final exam. Required online mini quizzes are given about once per week. The final grade in the course is calculated as follows (100pts total):

Midterm exam	30pts
Comprehensive final	40pts
Homework Problems	24pts (4pts each set)
Online mini quizzes	6pts (0.5pt each)
Challenge Problem	10pts (Maximum - Extra Credit)

I do not grade on a curve. Grades are assigned by:

A: 100-90pts
B: 89-80pts
C: 79-70pts
D: 69-60pts
E: Below 60pts

Class notes: Class notes, homework solutions and other information are provided on the D2L website under the "Content" menu bar item. The posted class notes are selected chapters from an upcoming book entitled "Laser Light Engineering." They are the primary reading resource for the class. Not all of the material contained in LLE chapters will be discussed in the lectures. Students are responsible only for the material covered in lectures.

In-class lectures: The primary lecture resource for the class is in the form of in-class lectures, which are also available as recoded videos shortly after the lecture is complete. Instructions for viewing the videos will be posted on the D2L web page "News" section and distributed via email. At times when the instructor is away on travel, pre-recorded lectures will be available that cover content of the missing in-class lectures.

Recitation: An online recitation class will be held on Thursday evenings starting at 6pm. During recitation, I will go through detailed development of important equations, answer questions, and go over mini-quiz and homework problems. See D2L for details.

Detailed online mini-quiz information: Twelve online mini-quizzes (0.5pt each) are given during the semester through the D2L website (Login at http://d2l.arizona.edu). Points accumulated through working the mini quizzes will count as credit for the class. Each quiz covers one or more lectures of material. Quizzes are a combination of randomized multiple choice and true-false questions. You need a UA NetID in order to logon to the system and take quizzes. Quizzes are available at any time during the semester, once they are posted. Quizzes have a time limit of 10 minutes, once you start the quiz. You may use any resource, other than another person, in order to work the online mini-quizzes. Each quiz has five questions, which are worth 0.1pts each. You are allowed an infinite number of attempts to take each quiz. Your final score for each quiz is the highest score of all attempts by the completion time that is posted. Online mini quizzes must be completed by midnight on the day according to the schedule shown below. Distance students have an additional week to complete the mini quizzes.

Homework problems: Homework problems are listed in the course notes and schedule outline. Homework is uploaded into D2L and is checked for completeness by the grader. Late submissions are not accepted. Solutions to all problems are posted on D2L. Distance students have an additional week to turn in the problems.

Midterm exam information: This exam is problem oriented and will cover Sections 1 through 3A. Problems are similar to homework problems and appropriate sections of written comprehensive/qualifying exam questions. This exam will be administered through D2L, where exam questions are posted during a fixed time period once you start the exam. Your answers and work pages must be scanned and uploaded into D2L within 30 minutes of exam completion.

Final comprehensive exam: The final exam is administered at a time determined by the UA listing for final exams, as listed below. This comprehensive exam covers all material in the class. The exam questions are problem oriented and are variations of 505R written Comprehensive/Qualifying Exam questions drawn from approximately the last 25 years. Like the midterm exam, the final exam will be administered through D2L, where exam questions are posted during a fixed time period once you start the exam. Your answers and work pages must be scanned and uploaded into D2L within 30 minutes of exam completion.

Challenge Problem: Students may work in groups of up to three persons to analyze a problem that will be provided by the instructor. A written report with a maximum of five pages in length must be submitted by 5pm on the last day of classes on D2L to receive credit. The instructor will provide further information on this extra-credit task within a few weeks of the start of classes.

Distance Students: As a general rule, distance students will be given an extra week to complete assignments and exams from the dates posted below. For exams, the grader will organize time windows compatible with distance student schedules if they cannot attend the posted online exam times. Additional considerations for distance-student due dates will be considered, depending on the circumstances.

Academic integrity: All students are expected to follow the University of Arizona Code of Academic Integrity. Violations will be immediately sanctioned, according to the guidelines found at: http://deanofstudents.arizona.edu/codeofacademicintegrity.

Attached you will find a tentative outline, schedule, and recommended texts.

Optics 505 – Diffraction and Interferometry

TOPICAL LIST OF SUBJECTS

1) Introduction
   a) Administrative items
   b) Introduction to interferometry and diffraction
   c) Mathematical preliminaries
2) SECTION 1: Waves and Polarization (LLE Chapter 3)
   a) Scalar, one-dimensional analysis
      i) Transverse waves
      ii) Linear superposition
      iii) Beats
      iv) Standing waves
   b) Plane waves
   c) Spherical Waves
   d) Polarization
      i) Linear polarization
      ii) Circular polarization
      iii) Elliptical polarization
      iv) Ellipticity
      v) Jones calculus
      vi) Stokes parameters and Mueller calculus
      vii) Degree of polarization
3) SECTION 2: Interference and Interferometry (LLE Chapter 4)
   a) Basic two-beam interference
      i) Two plane waves
      ii) Two spherical waves
      iii) Plane wave and spherical wave
      iv) Plane wave and cylindrical wave
      v) Two cylindrical waves
   b) Classical two-beam interferometers
      i) Methods of beam division
      ii) Young's double-pinhole interferometer (YDPI)
      iii) Young's double-slit interferometer (YDSI)
      iv) Lloyd's mirror
      v) Fresnel's mirrors
      vi) Fresnel's biprism
      vii) Twyman-Green
      viii) Mach-Zehnder
      ix) Michelson
      x) Fizeau and Newton's rings
      xi) Plane parallel plate
      xii) Fizeau and Newton's Rings
      xiii) Lateral shear
      xiv) Radial shear
      xv) Polarization splitters

xvi) Diffraction gratings

c) Multiple Beam Interference
   i) Airy's formula
   ii) Absorbing coatings
   iii) Fabry Perot (plane and spherical)

d) Multilayer Films (Separate notes)
   i) Theory
   ii) AR film
   iii) High reflectance film

4) SECTIONS 3A and 3B: Scalar Diffraction (LLE Chapter 5)

SECTION 3A:

a) Introduction
b) Mathematical Description of Diffraction
   i) Integral Theorem of Helmhotz and Kirchhoff
   ii) Diffraction by a plane screen
   iii) Huygens-Fresnel Principle
   iv) Derivation of a Huygens wavelet
   v) Transfer function of free space
   vi) Angular spectrum of plane waves
   vii) Talbot effect
   viii) Babinet's principle

SECTION 3B:

c) Fresnel Diffraction
   i) Fresnel zones
   ii) Fresnel diffraction from apertures
   iii) Poisson's spot
   iv) Fresnel zone plates
   v) Edge diffraction
   vi) Atlas of diffraction patterns in the near field
d) Fraunhofer Diffraction
   i) Circular aperture
   ii) Exit pupil of an imaging system
   iii) Rectangular aperture
   iv) Diffraction from slits
e) Theory of Gratings
   i) Geometric OPD theory
   ii) Fraunhofer diffraction from thin gratings
   iii) Thick gratings and Bragg diffraction

5) SECTION 4: Coherence and fringe localization (LLE Chapter 6)
   a) The mutual coherence function
   b) Two-wavelength point source
   c) Power spectrum
   d) Basic temporal coherence
   e) Basic spatial coherence
   f) van Cittert – Zernike
   g) Coherence area
   h) Terminology
   i) Fringe localization
6) SECTION 5: Optical Transfer Function – OTF
   a) Coherent imaging
   b) Incoherent imaging
7) Direct Phase Measurement (through additional lecture)

   a) Methods of phase shifting
   b) Algorithms
8) Holography (through optional lectures – no exam questions)
   a) Physical description
   b) Mathematical proof of reconstruction process
   c) Minimum reference beam angle to separate orders
   d) Recording and playback geometry
   e) Light sources and recording materials
   f) Volume holograms
   g) Applications
9) Speckle (through optional lectures – no exam questions)
   a) Physical origin
   b) Applications

Class No:	Date:		Material Covered	
			Syllabus, Background,	
1	16-Jan	(Th)	LLE Ch 3	
	20-Jan	(M)		**NO CLASS - MLK Holiday**
2	21-Jan	(Tu)	LLE Ch 3	
3	23-Jan	(Th)	LLE Ch 3	
	24-Jan	(F)		HW 1, MQ 1 (DUE 5:00 PM)
4	28-Jan	(Tu)	LLE Ch 4	
5	30-Jan	(Th)	LLE Ch 4	
	31-Jan	(F)		MQ 2 (5:00 PM)
6	4-Feb	(Tu)	LLE Ch 4	
7	6-Feb	(Th)	LLE Ch 4	
	7-Feb	(F)		MQ 3 (5:00 PM)
8	11-Feb	(Tu)	LLE Ch 4	
9	13-Feb	(Th)	LLE Ch 4	
	14-Feb	(F)		MQ 4 (5:00 PM)
10	18-Feb	(Tu)	LLE Ch 4, Thin Films	(Industrial Affiliates - Online Video Only)
11	20-Feb	(Th)	Thin Films	
	21-Feb	(F)		HW 2, MQ 5 (5:00 PM)
12	25-Feb	(Tu)	LLE Ch 5	
13	27-Feb	(Th)	LLE Ch 5	
14	4-Mar	(Tu)	LLE Ch 5	
15	6-Feb	(Th)	LLE Ch 5	
	7-Mar	(F)		HW 3, MQ 6 (5:00 PM)
	11-Mar	(Tu)		**SPRING RECESS – NO CLASSES**
	13-Mar	(Th)		
	17-Mar	(M)		**MIDTERM EXAM OPTION 1** (6-8pm)
16	18-Mar	(Tu)	LLE Ch 5	
	19-Mar	(W)		**MIDTERM EXAM OPTION 2** (6-8pm)
17	20-Mar	(Th)	LLE Ch 5	
	21-Mar	(F)		MQ 7 (5:00 PM)
18	25-Mar	(Tu)	LLE Ch 5	
19	27-Mar	(Th)	LLE Ch 5	
	28-Mar	(F)		MQ 8 (5:00 PM)
20	1-Apr	(Tu)	LLE Ch 5	
21	3-Apr	(Th)	LLE Ch 6	
	4-Apr	(F)		HW 4, MQ 9 (5:00 PM)
22	8-Apr	(Tu)	LLE Ch 6	
23	10-Apr	(Th)	LLE Ch 6	
24	15-Apr	(Tu)	LLE Ch 6	
25	17-Apr	(Th)	LLE Ch 6	
	18-Apr	(F)		MQ 10 (5:00 PM)
26	22-Apr	(Tu)	LLE Ch 6, OTF	
27	24-Apr	(Th)	OTF	
	25-Apr	(F)		HW 5, MQ 11 (5:00 PM)
28	29-Apr	(Tu)	OTF	
29	1-May	(Th)	OTF	
	2-May	(F)		
30	6-May	(Tu)	OTF	
	7-May	(W)		HW6 and MQ 12 (5:00 PM)

COMPREHENSIVE FINAL EXAM: Tuesday, May 13, 8 am to 10 am, in class or over D2L

HOMEWORK PROBLEMS AND DUE DATES (by 5pm)

HW #	Due Date (by 5pm)	Problems	Notes
1	Friday, January 24	HW 1: 3-2, 3-3, 3-7, 3-11, 3-13, 3-22	Irradiance $I = c\varepsilon_0 \left\langle E^2 \right\rangle$, where c = speed of light in vacuum, epsilon_0 is permittivity of free space, and angle brackets are time average. Visibility = (Imax-Imin)/(Imax +Imin). In Problem 3-3, use P (W) = integral of irradiance (W/m^2). E is in units of Volt/m.
2	Friday, February 21	HW 2: 4-2, 4-7, 4-14, 4-15, 4-16, 4-18, 4-23, and 4-37	Review additional Thin Films notes.
3	Friday, March 7	HW 3: 5-2b, 5-4, 5-5, 5-12	
4	Friday, April 4	HW 4: 5-10, 5-11, 5-16, 5-18, 5-21, 5-25, 5-27, 5-28	
5	Friday, April 25	HW 5: 6-5, 6-6, 6-8, 6-9, 6-13, 6-15	
6	Wednesday, May 7	HW 6: 8-1, 8-2, 8-5, 8-8	

MINI QUIZ DUE DATES (by 12 midnight)

MQ	Due Date (by midnight)
1	Friday, January 24
2	Friday, January 31
3	Friday, February 7
4	Friday, February 14
5	Friday, February 21
6	Friday, March 7
7	Friday, March 21
8	Friday, March 28
9	Friday, April 4
10	Friday, April 18
11	Friday, April 25
12	Wednesday, May 7

OPTI 505R -
Reading Assignments – S2024

Lectures	Reading Suggestions
1	Introduction, LLE Ch 3: 3.0 through 3.2, 3.4.1.1
2	LLE: 3.4.1.2 through 3.4.2.2
3	LLE: 3.4.2.3 through 3.4.2.6, and 3.4.3
4	LLE: 4.0 through 4.1.1.4
5	LLE: 4.1.2 through 4.1.3
6	LLE: 4.2.0 through 4.2.7
7	LLE: 4.2.8 through 4.2.12
8	LLE: 4.2.13 and 4.2.14
9	LLE: 4.3
10	Thin Film Notes
11	Thin Films Notes
12	LLE: 5.1 through 5.2.3
13	LLE: 5.2.4 through 5.2.7
14	LLE: 5.2.9
15	LLE: 5.2.10 through 5.2.12
16	LLE: 5.3.1
17	LLE: 5.3.2 and 5.3.5
18	LLE: 5.3.4
19	LLE: 5.4
20	LLE: 5.5
21	LLE: 6.1 through 6.3.2
22	LLE: 6.3.3
23	LLE: 6.4 through 6.4.3
24	LLE: 6.4.4 and 6.4.5
25	LLE: 6.6
26	LLE: 8.1
27	LLE: 8..2.1 and 8.2.2
28	LLE: 8.2.3 through 8.2.3.2
29	LLE: 8.2.3.3
30	