OPTI 509
Statistical Optics

Instructor: Prof. Amit Ashok
Lecture Time:
Monday/Wednesday 9:30 am-11:45 am

Office Hours:
Monday/Wednesday/Friday 1-2pm
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1 Pre-requisites

OPTI 501, Electromagnetic Waves
OPTI 508*, Probability and Statistics in Optics
may be waived with instructor's permission.

2 Course Description

Learn and understand the statistical nature of optical fields via concepts like spatial and temporal coherence. The second-order coherency theory of optical fields is crucial to gain a deeper understanding of how optical instruments/systems such as interferometers and imaging systems measure optical fields and underlying information. Based on the concepts learnt in this class you will be able to analyze partial coherence in imaging systems (e.g. microscopes), Fourier transform spectroscopy (FTIR), stellar interferometry, optical coherence tomography (OCT), gravitational wave sensing (LIGO).

3 Course Objectives

Upon completion students will be able to do the following:

(a) Familiar with the fundamental statistical nature of optical fields.

(b) Employ stochastic processes to represent optical fields.

(c) Understand the concept of temporal coherence and spatial coherence.

(d) Understand the relationship between spatial coherence and source spatial distribution via the Van-Cittert-Zernike theorem.

(e) Understand the relationship between temporal coherence and source spectral distribution via the Weiner-Khinchin theorem.

(f) Learn the propagation of coherence function through free-space and simple optical elements.

(g) Learn to apply second-order coherence theory to optical systems e.g., stellar interferometers and imaging systems.

4 Textbook

- J. Goodman,*Statistical Optics*, 2000, Wiley-Interscience Publication.

5 Supplementary Reading

- A. Papoulis and S. Pillai, *Probability, Random Variables and Stochastic Processes*, 2001, McGraw-Hill Companies.
- L. Mandel and E. Wolf, *Optical Coherence and Quantum Optics*, 2008, Cambridge University Press.
- E. Wolf, *Introduction to Coherence and Polarization of Light*, 2007, Cambridge University Press.

6 Class Website

The course's online component will be conducted via the University of Arizona's D2L software system. The D2L can by accessed by this link: `www.d2l.arizona.edu`.

7 Course Grade Breakdown

The final grade for the class will have following components:

1. Homeworks: 33%
2. Midterm Exam: 33%
3. Final Class Project: 34%

8 Grading Scale

The class grades will depend on the class score statistics. However, nominally the following scores ranges will be used to assign the class grade:

- 100%-87%: A
- 75%-86%: B
- 65%-74%: C
- 55%-64%: D
- 0%-54%: E

9 Academic Integrity

Integrity and ethical behavior are expected of every student in all academic work. This Academic Integrity principle stands for honesty in all class work, and ethical conduct in all labs and clinical assignments. This principle is furthered by the student Code of conduct and disciplinary procedures established by **ABOR Policies 5-308 through 5-404**, all provisions of which apply to all University of Arizona students. The Code of Academic

Integrity is intended to fulfill the requirement imposed by **ABOR Policy 5-403.A.4** and otherwise to supplement the Student Code of Conduct as permitted by **ABOR Policy 5-308.C.1**.

For more details please see:
`http://deanofstudents.arizona.edu/codeofacademicintegrity`

You are expected and encouraged to consult with your colleagues in the preparation of your homework assignments. As I stated above, homework assignments are for the benefit of the student, so if you do not understand the homework you are the only one that will suffer. However, please do not insult your colleagues or me by turning in directly copied homework. If you work with a colleague closely enough that your solutions might appear (legitimately) to be copied, then please disclose the collaboration on the top of the page. It is quite acceptable to consult references, other course notes, other faculty, senior graduate students, etc., in preparing your solutions. However, any consultation with an outside source that contributes significantly to the solution you turn in should be disclosed.

10 Topics Covered

1. **Review of probability and random variables (1 lecture)**
   (a) Definition of probability and random variables
   (b) Distribution and density function
   (c) Bivariate and multivariate random variables
   (d) Joint, conditional, and marginal densities
   (e) Characteristic function, moment generating function
   (f) Transformation of random variables
   (g) Complex-valued random variables and random phaser sums
2. **Stochastic processes (2 lectures)**
   (a) Definition in terms of random variables and ensemble functions
   (b) Ergodicity and stationarity
   (c) Auto-correlation, cross-correlation, and Wiener-Khinchin theorem
   (d) Gaussian and Poisson random processes
   (e) Karhunen-Loeve expansion
   (f) Linear transformation of stochastic process
3. **First-order properties of optical waves (4 lectures)**
   (a) Monochromatic, non-monochromatic and narrowband light
   (b) Polarized and unpolarized thermal light
   (c) Partially polarized thermal light
   (d) Laser light and pseudo-thermal light
4. **Second-order coherence theory (12 lectures)**
   (a) Temporal coherence and complex degree of self coherence
   (b) Spatial coherence and complex degree of mutual coherence
   (c) Cross-spectral purity
   (d) Propagation of mutual coherence
   (e) The Van Cittert-Zernike theorem
5. **Applications of second-order coherence theory (11 lectures)**
   (a) Stellar Interferometry
   (b) Fourier Transform Spectroscopy
   (c) Optical Coherence Tomography
   (d) Partial coherence in imaging systems
   (e) Speckle/Memory-effect Imaging
   (f) Gravitational Sensing (LIGO)