

OPTI 509

Statistical Optics

Instructor: Amit Ashok
Lecture Times (RM 305):
Monday/Wednesday 11am-12:15pm

Office Hours (RM 421):
Monday/Wednesday 1-2pm
Discussion Hour (RM 305):
Friday 9-9:50am
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TA: Aytekin Ozdemir
Office Hours (RM 747):
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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 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 optical instruments/systems such as interferometers and imaging systems. Based on the concepts learnt in this class you will be able to analyze partial coherence in imaging systems, laser speckle, and propagation in random medium.

3 Course Objectives

Upon completion students will be able to do the following:

- (a) Familiar with the statistical nature of optical fields.
- (b) Learn to use 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 real 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 be accessed by this link: www.d2l.arizona.edu.

7 Distance Learning

The class will be offered via distance learning when possible.

8 Topics Covered

8.1 Review of probability and random variables (3 lectures)

- (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

8.2 Stochastic processes (5 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

8.3 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

8.4 Second-order coherence theory (10 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

8.5 Applications of second-order coherence theory (10 lectures)

- (a) Laser speckle
- (b) Stellar interferometry
- (c) Fourier transform spectroscopy
- (d) Partial coherence in imaging systems
- (e) Propagation through random inhomogenous media

9 Assignments

The final grade for the class will have following components:

- (a) Homeworks: 25%
- (b) Class project: 25%
- (c) Midterm Exam: 25%
- (d) Final Exam: 25%

10 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.

11 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%-90%: A
- 75%-89%: B
- 65%-74%: C
- 55%-64%: D
- 0%-54%: E

Class Schedule (Tentative)

Week	Date	Topics Covered	Class/Exams
Week 1	August 20	Introduction	
	August 22	Probability and RV	
Week 2	August 27	Dist./Density/Joint/Conditional	
	August 29	Charac./Trans./Complex RV	
Week 3	September 3	Labor Day	No Class
	September 5	RV/Ensemble/Stationary/Ergodic	
Week 4	September 10	Auto/Cross Correlation/ Weiner-Khinchin	
	September 12	Gaussian/Poisson RP	
Week 5	September 17	Karhunen-Loeve/Linear Transform	
	September 19	Mono and non-mono./Narrowband light	HW 1 Due
Week 6	September 24	Polarized/Unpolarized Thermal Light	
	September 26	Laser and pseudo-thermal light	
Week 7	October 1	Temporal Coherence	HW 2 Due
	October 3	Complex Degree of Self Coherence	
Week 8	October 8	Spatial Coherence	HW 3 Due
	October 10	Complex Degree of Mutual Coherence	
Week 9	October 15	<i>In class mid-term exam</i>	Mid-Term
	October 17	Cross-spectrum	
Week 10	October 22	Van Cittert-Zernike theorem	HW 4 Due
	October 24	Propagation of Mutual Coherence	Project proposal
Week 11	October 29	Propagation of Mutual Coherence	
	October 31	Partial Coherence in Imaging	HW 5 Due
Week 12	November 5	Partial Coherence in Imaging	
	November 7	Partial Coherence in Imaging	HW 6 Due
Week 13	November 12	Fourier Transform Spectroscopy	
	November 14	Stellar Interferometry	
Week 14	November 19	Veteran Day	No Class
	November 21	Laser Speckle	Travel/Video Class HW 7 Due
Week 15	November 26	Laser Speckle	
	November 28	Propagation through Random Medium	HW 8 Due
Week 16	December 3	Propagation through Random Medium	
	December 5	Review / Project Presentation	Project Report Due
Week 17	December 10	10:30am-12:30pm	Final Exam

Name	Major/Minor	MS/PhD	Grade/Audit