Statistical Optics ECE 510/610

Course Description

This is an advanced course in which we explore the field of Statistical Optics. Topics covered include such subjects as the statistical properties of natural (thermal) and laser light, spatial and temporal coherence, effects of partial coherence on optical imaging instruments, effects on imaging due to randomly inhomogeneous media, and a statistical treatment of the detection of light. Development of this more comprehensive model of the behavior of light draws upon the use of tools traditionally available to the electrical engineer, such as linear system theory and the theory of stochastic processes.

Prerequisites: Fourier Optics or permission of the instructor

Objective

The objective of this course is to equip the student to deal with a variety of problems of contemporary interest in the field of optics. Examples of such problems are speckle effects in synthetic aperture radar, stellar speckle interferometry, propagation through atmospheric turbulence, design of optical instruments, Fourier transform spectroscopy, etc.

Course Outline

Lecture	Topic
1-2	Review of random variables and stochastic processes: joint moments (of a GRV) higher than two, characteristic functions, zero mean circular GRV's, doubly stochastic Poisson processes, binomial and multinomial PDF's, transformations of PDF's
3-4	Analytic signals, Jones vector/coherency matrix and Stokes/Mueller matrix representations of polarization, first-order properties of natural (thermal), laser, and pseudo-thermal radiation
5-7	Coherence of optical waves: temporal and spatial coherence, the degeneracy parameter, propagation of mutual intensity, the generalized Van Cittert-Zernike theorem, Schell's theorem, cross-spectral purity, Gaussian-Schell beam waves, the pinhole camera
8-10	Problems involving higher order coherence: statistical moments of integrated intensity, the K. L. expansion, statistical moments of mutual intensity with finite measurement time, the intensity interferometer
11-12	Effects of partial coherence on imaging systems, imaging as an interferometric process, laser speckle characterization and applications
13-14	Computational methods in optics: Monte Carlo techniques, producing random numbers that obey a prescribed PDF, the concepts of information content and entropy
15-17	Imaging in the presence of randomly inhomogeneous media: random apodizing and phase shifting screens (the PSF/OTF for strong scatter), characterization of turbulence, propagation through turbulent media, the long & short exposure OTF's, limiting resolution looking through the atmosphere, stellar speckle interferometry, phase recovery, the Extended Huygens-Fresnel Principle

18-20 Fundamental limits to the photoelectric detection of light, the degeneracy parameter for natural and laser radiation, classical vs. shot noise, the intensity interferometer at low light levels

Text

Statistical Optics, J. W. Goodman, John Wiley & Sons, 1985, ISBN 0-471-01502-4.

References

Radiometry and the Detection of Optical Radiation, R. W. Boyd, Wiley, 1983.

The Computer in Optical Research, Methods and Applications, B. R. Frieden, ed, Springer-Verlag, 1980.

Probability, Statistical Optics, and Data Testing: A Problem Solving Approach, Third Edition, B. R. Frieden, Springer, 2001

Speckle Phenomena in Optics: Theory and Applications, J. W. Goodman, Roberts and Company, 2007

Introduction to Statistical Optics, E. L. O'Neill, Addison-Wesley, 1963.

Probability, Random Variables, and Stochastic Processes, 4th edition, A. Papoulis and S. Unnikrishna Pillai, McGraw-Hill, 2001

The New Physical Optics Notebook: Tutorials in Fourier Optics, G. O. Reynolds, J. B. DeVelis, G. B. Parrent, Jr., B. J. Thompson, SPIE Optical Engineering Press, 1989.

Project Requirement

Report (10-20 pages) on a subject of relevance to the course content

Course Grading Policy

Paper (10%), Homework (30%), Midterm (30%), Final Exam (30%)