Fourier Techniques in Optics

Course Description

Optics is presented from the perspective of linear systems theory. This viewpoint arose from the cross-fertilization that began in the 1930's between traditional optics and the more modern Fourier techniques. The course builds on and extends the mathematical tools traditionally available to the undergraduate engineer, Fourier analysis and linear systems theory. Topics include scalar diffraction theory, Fourier transforming and imaging properties of lenses, spatial frequency analysis of optical systems, spatial filtering and information processing, and holography. Applications of these concepts include non-destructive evaluation of materials and structures, remote sensing, and medical imaging.

Objective

The goal of this course is to acquaint the student with the modern spatial frequency theory of optical systems and to provide insight into the use of light as a remote measurement tool. The course will extend concepts and mathematical tools already at the student's disposal; emphasis will be on the link between these concepts and tools, and physical observables.

Course outline

Lecture	Topic
1	Why "Fourier" Optics?; the propagation of light, plane waves, eigenfunctions, analytic signals, various Fourier transforms, properties of the Fourier transform
2	Analysis of two-dimensional linear systems, two-dimensional sampling, Green's functions
3	Scalar diffraction theory, various boundary conditions leading to the Huygens-Fresnel diffraction principle, generalization to non-monochromatic sources, concept of a plane wave spectrum, apertures as band-limiting functions
4	Various approximations to the Huygens-Fresnel formula (Fresnel and Fraunhofer), concept of the free-space propagator as an impulse response function, Rayleigh range of an aperture
5	Fresnel wavefront division, zone plates, self-imaging objects
6	Imaging and transforming properties of thin lenses, asymptotic approximations, method of stationary phase, non-diffracting beams
7	Fourier analysis of optical systems, temporal and spatial coherence, coherent and incoherent systems, aberrations
8	Three-dimensional imaging (confocal microscopy), tomographic concepts, imaging system performance evaluation (interferometric determination of optical transfer functions, knife-edge measurement of point-spread functions)
9	Spatial filtering, optical signal processing, frequency domain synthesis, Vander Lugt filters, spatial light modulators, tomographic imaging modalities
10	Laser speckle, speckle correlation techniques in non-destructive evaluation
11	Interferometric speckle techniques, electronic speckle pattern interferometry (ESPI)

12 Treatment of polarization using the Jones calculus and Stokes-Mueller formalism

13 Principles of wavefront reconstruction (holography), film-based and solid state detectors, computer-generated holograms, optical and numerical reconstruction techniques

14 Holographic concepts in non-destructive test and evaluation

Text

Introduction to Fourier Optics, Third edition, J. W. Goodman, Roberts & Company 2004, ISBN 0-9747077-2-4.

References

Principles of Optics, M. Born, E. Wolf, Pergamon Press, Sixth Edition, 1980.

Fourier Analysis and Imaging, R. N. Bracewell, Springer, 2004.

Linear Systems, Fourier Transforms, and Optics, J. D. Gaskill, John Wiley & Sons, Inc., 1978.

Statistical Optics, J. W. Goodman, John Wiley & Sons, Inc., 1985.

Speckle Phenomena in Optics, J. W. Goodman, Roberts & Company 2007.

Optical Holography: Principles, Techniques, and Applications, P. Hariharan, Cambridge University Press, 1984.

Fundamentals of Optics, F. A. Jenkins, and H. E. White, McGraw-Hill Book Co., Fourth Edition, 1976.

Holographic and Speckle Interferometry. A discussion of the theory, practice and applications of the techniques, R. Jones, Catherine Wykes, Cambridge University Press, Cambridge, 1983.

Optical Shop Testing, D. Malacara, Wiley-Interscience, Third Edition, 2007.

Introduction to Statistical Optics, E. L. O'Neill, Dover Publications, 2004.

Systems and Transforms with Applications to Optics, A. Papoulis, McGraw-Hill Book Co., 1968.

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

Holographic Interferometry in Experimental Mechanics, Yu. I. Ostrovsky, V. P. Shchepinov, V. V. Yakoulev, Springer-Verlag, Berlin 1991.

Course grading policy

Homework (33%), Midterm (33%), Final Exam (33%)