INTRODUCTION TO FOURIER OPTICS

Some course notes will be distributed

Other Readings:

RIT Course Catalog Description:
This course presents a unified view of the formation of images and image quality of an optical system from an applications viewpoint, but with a strict mathematical development. Topics covered are: ray and wave theory of imaging, image quality measurements, image formation with coherent and incoherent light, and optical information processing. (nominal prerequisite is 1051-737, 1051-717 is also sufficient) Class 4, Credit 4 (S)

Actual Description:
This course develops a mathematical description of optical image formation via mathematical modeling of light propagation through the imaging system by application of the principles of linear systems. The model is based on approximations of Huygens’ principle that light propagates via spherical wavelets. The propagation of light from plane to plane is modeled as a convolution with the impulse response appropriate to the model. The action of the optical element is a multiplication of the complex amplitude by the appropriate phase function. The mathematical description is based on the so-called “chirp Fourier transform”.

The course will develop the model for the single-wavelength case (“coherent” light) and will be generalized to the “incoherent” case, including a description of appropriate metrics for the optical system. Holographic imaging will also be considered.
Homework:
  Problem sets will be handed out
  Assignments due as scheduled, typically (but not necessarily) one week later
  There may be some computer homework, with two-week deadline.
  I encourage you to work together on problems, but you must hand in your own answers.

Final Examination:
  I suggest a take-home open-book problem set.
1. Review of the Fourier transform (Goodman §2)
   i. Cartesian-separable special functions
      1.i.1 Dirac delta function $\delta[x,y]$
      1.i.2 RECT$x,y$
      1.i.3 quadratic-phase function
   ii. Circularly symmetric special functions
      1.ii.1 CYL$(r)$
      1.ii.2 $\delta(r - r_0)$
   iii. Convolution
   iv. Fourier transform of separable special functions
   v. Fourier transform of circularly symmetric functions
   vi. Method of stationary phase

2. Wave Equation and Systems Analysis of Light Propagation
   i. Huygens’ principle, diffraction integrals
   ii. Measurable electromagnetic quantities: power
   iii. Quadratic phase factors
   iv. Impulse response and transfer function of light propagation
   v. Asymptotic evaluation of the diffraction integral in the Fresnel and Fraunhofer regions
   vi. Fresnel transform
   vii. Effect of apertures and lenses on plane wave spectra: Abbé’s theory
   viii. Uncertainty in fields and transforms
   ix. Coherence of light

3. Imaging Properties of Lenses from the Viewpoint of the Plane Wave Spectrum
   i. Plane wave spectrum analysis
   ii. Transfer function in coherent light
   iii. Transfer function in incoherent light
   iv. Modulation transfer function (MTF) of a perfect lens
   v. Sampling of fields and transforms, relation to information theory

4. Imaging Properties of Lenses from Viewpoint of Diffraction Integral
   i. Thin lens as “quadratic phase plate”
   ii. Fourier transforming property of lenses, shift-variant systems
   iii. Action of lens for plane waves and spherical waves

5. Metrics of Optical Image Quality
   i. Optical transfer function and point spread functions in coherent and incoherent light
   ii. Modulation Transfer Function

6. Optical Information Processing
   i. 4f correlator
   ii. Optical Transfer Function Synthesis
   iii. Incoherent processing by geometrical optics
   iv. Holography and computer-generated holography
   v. Optical matched filtering
   vi. Spatial carrier techniques