

1051-733 Optics Course Outline

Chapter References:

(H) = Hecht, *Optics*

(BW) = Born and Wolf, *Principles of Optics*

(P3) = Pedrotti. et al., *Introduction to Optics*

(PON) = *New Physical Optics Notebook*, Reynolds, De Velis, Parrent, Thompson

(G) = *Linear Systems, Fourier Transforms, and Optics*, Gaskill

I. Wave Optics and Imaging

- A. Review of wave equation (P3 §4, BW §1, H §2)
- B. Electric and magnetic fields (BW §1, H §3)
- C. Review of Maxwell's equations, propagation of electromagnetic fields (BW §1, H §3.2)
- D. Vector Calculus
 - 1. vector and scalar fields
 - 2. Gradient of scalar field \rightarrow vector field
 - 3. Divergence of vector field \rightarrow scalar field
 - 4. Curl of 3-D vector field \rightarrow 3-D vector field
 - 5. Laplacian of scalar and vector fields
- E. Electromagnetic waves

II. Diffraction of light (H §10), (BW §8), (PON §9)

- A. Huygens' principle (H §10.1, BW §8.2, G §10.2)
- B. Fresnel-Kirchhoff Diffraction Integral (BW §8.3)
 - 1. Spherical waves
 - 2. Linearity and shift variance of process
- C. Fresnel Diffraction (H §10.3, PON §9, P3 §13, BW §8, G §10.3)
 - 1. Propagation from point sources as paraboloidal waves
 - 2. Linearity and shift invariance, impulse response of propagation in Fresnel diffraction, quadratic-phase factors (H §10.3.1)
 - 3. Transfer function of light propagation in Fresnel diffraction, quadratic phase factor
 - 4. Fresnel diffraction from a straight edge, Cornu spiral (BW §8.7)
 - 5. Fresnel diffraction from a rectangular aperture (H §10.3.6)
 - 6. Fresnel diffraction from a circular aperture (H §10.3.2)
 - 7. Fresnel zone plates (H §10.3.5)
- D. Fraunhofer Diffraction (H §10.2, BW §8.5, P3 §11, G §10.4)
 - 1. Approximation to spherical waves as plane waves, linear shift-variant process
 - 2. Relationship to Fourier Transform
 - 3. Diffraction from slits
 - 4. Single-slit diffraction (H §10.2.1, P3 §11.1)
 - 5. Two-slit diffraction (H §10.2.2, P3 §11.5)
 - 6. Many-slit diffraction, diffraction gratings (H §10.2.3, P3 §11.6)
 - 7. Diffractive spreading of a beam (P3, §11.2)
 - 8. Rectangular and circular apertures; Airy disk (H §10.2.4, §10.2.5, P3 §11.3)

III. Optical imaging in the diffraction model

- A. Action of lenses with spherical surfaces (G §10.6)
- B. Quadratic-phase model of lenses
- C. Propagation, multiplication, propagation (*C-M-C* model of optical system) (H §11.3.3)
- D. Imaging Equation:
$$\frac{1}{z_1} + \frac{1}{z_2} = \frac{1}{f}$$
- E. Coherence
- F. Diffraction limit

- G. Different criteria for resolution: Dawes' limit, Rayleigh criterion, Sparrow criterion (H §10.2.6, PON §13.3)
- H. Metrics of Optical Imaging System Performance
 - 1. Modulation Transfer Function (MTF) and Point Spread Function (psf) (H §11.3.5)
 - 2. Strehl ratio (BW §9, G §11.7)
- I. Interaction of light and matter (H §4.2, P3 §25, BW §2)
 - 1. Refractive Index and Dispersion
 - 2. Lorentz model for refractive index
- IV. Fresnel Equations and Applications (H §4.6) (BW §1.5)
 - A. Boundary Conditions at an Optical Interface (H §4.6.1) (BW §1.5.1)
 - B. Derivation of Fresnel Equations for TE and TM Polarizations (H §4.6.2) (BW §1.5.2)
 - C. Reflectance and Transmittance Curves (H §4.6.3) (BW §1.5.3)
 - D. Polarization Angle; Brewster Windows
 - E. Total Internal Reflection (TIR) (H §4.7) (BW §1.5.4)
 - F. Evanescent Wave, Frustrated TIR; Beam Splitters (H §4.7.1)
 - G. Phase Change on Reflection
- V. Optical Interference and Interferometers (BW §7, P3 §7,
 - A. Division of wavefront (PON §22, P3 §7, H §9.3)
 - 1. addition of waves
 - 2. Young's interferometer
 - B. Division of amplitude (PON §23, P3 §8, H §9.4)
 - 1. Fizeau interferometer
 - 2. Michelson and Twyman-Green interferometers
 - 3. Mach-Zehnder interferometer
 - 4. Sagnac interferometer
 - C. Interference by multiple reflections (H §9.6, P3 §7.9, PON §24)
 - 1. Thin films
 - 2. Fabry-Perot interferometer
- VI. Geometrical Optics and Imaging
 - A. Transition from wave to ray optics
 - B. Fermat's Principle (P3 §2.2, H §4.5, BW §3.3)
 - C. Refraction at a Spherical Surface
 - 1. Paraxial approximation, imaging equation
 - 2. Nature of Objects and Images
 - D. Imaging With Lenses (H §5, P3 §2.6, §3)
 - 1. Transverse Magnification
 - 2. Longitudinal Magnification
 - 3. Spherical Mirrors
 - 4. Third-Order (Seidel) Aberrations
 - 5. Systems of Thin Lenses
 - 6. Effective Focal Length
 - 7. Cardinal Points
 - 8. Stops and Pupils
 - 9. System f-Number
 - E. Ray Tracing (H §6,
 - 1. Marginal and Chief Rays
 - 2. Paraxial Ray Tracing
 - 3. Matrix Methods
 - F. Computed Ray Tracing, OSLO™