

OPTI/ECE 527
Diffraction Optics and Holographic Principles

Instructor: *Raymond K. Kostuk*

Class Hours: *Tu/Th 2:00-3:15; Room: OSC 305*

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Lab: *ECE Rm 249*

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TA: TBD

Grading:

HWKs (~6): 20%

Lab(~3-4) 10% (Start in Mid-September)

Mid Term Exam: 25% (Mid October)

Class Paper: 10% (Last week of class)

Final Exam: 35%

Note: Labs and Class presentation not required for distance learning students. Grading for DLS: HWKs: 30%; MT Exam: 25%; Class paper (written only) 10%; Final: 35%

Recommended Text Books:

Note: *No textbook is required. I will provide notes from a preliminary version of my book. The book by Goodman is highly recommended and the new book by Toal also provides a good overview.*

1. J. W. Goodman, 'Introduction to Fourier Optics, 3rd ed.' McGraw Hill, 2005.
2. H. Coufal, D. Psaltis, and G. Sincerbox, 'Holographic Data Storage,' Springer, 2000.
3. V. Toal, 'Introduction to Holography,' CRC Press, 2011.

Lecture Content:

1. Basic concepts
 - a. Differences between holographic and intensity imaging
 - b. Historical background –X-ray diffraction, electron diffraction, ultrasound scattering, Lippmann photography
 - c. Overview of applications of holography

2. Introduction - terminology
 - a. Absorption and phase modulation
 - b. Thin and Thick gratings – Bragg condition
 - c. Transmission and Reflection gratings
 - d. Image properties – image fidelity
 - e. Diffraction efficiency
 - f. Interferometric and Computer Generated holograms
 - g. Recording geometries
 - h. Materials used for holography and material characteristics
3. Basic Holographic Recording Process
 - a. Construction, exposure, and reconstruction- real and virtual image
 - b. Relation between basic holographic processes and the response of photographic film
 - c. Enhanced scattering from a periodic structure – grating equation, grating period
 - d. Example – interference of two plane waves using propagation vectors
 - e. Grating vector – calculation from propagation vectors –examples
4. Analysis of Holographic Recordings – spatial frequency analysis
 - a. In-Line, Gabor type hologram – analytical equations
 - b. Analysis of zone plate –basic concepts of focus, phase matching at different locations on the aperture.
 - c. Off-axis hologram
5. Fourier Analysis of gratings
 - a. Review of Rayleigh Sommerfeld far-field diffraction formulas
 - b. Diffraction patterns from rectangular and circular apertures
 - c. Fourier analysis of periodic absorption and phase grating apertures
 - d. Fourier analysis of off-axis gratings
 - e. Different types of holograms characterized by Fourier properties.
6. Image analysis of holograms
 - a. Exact ray tracing
 - b. Aberrations of holographic lenses –basic aberration characteristics
 - c. Monochromatic aberrations.
 - d. Spectral dispersion of gratings
 - e. Modeling holographic optical elements
7. Hologram Recording Requirements
 - a. Coherence – temporal and spatial
 - b. Temporal coherence of sources with finite $\Delta\nu$ and Δt
 - c. Visibility, mutual degree of coherence
 - d. Coherence, polarization rotation effects on visibility
 - e. Coherence of multimode lasers

- f. Spatial filters
 - g. Ideal recording material properties
8. Coupled wave analysis
- a. Kogelnik's approximate coupled wave analysis
 - b. Basic description of diffraction efficiency modeling
 - c. Transmission holograms
 - d. Reflection holograms
 - e. DE of TE and TM polarization
 - f. Basic description of other types of approximate models – Raman Nath
 - g. Criteria for thin and thick holograms
 - h. Introduction to rigorous coupled wave analysis
 - i. Sequential and simultaneous hologram multiplexing
 - j. Wavelength and angular selectivity of volume holograms
 - k. Effects of absorption during construction
9. Holographic materials –recent developments
- a. Silver halide films
 - b. Dichromated gelatin
 - c. Holographic photopolymers
 - d. Photoresists
 - e. Photorefractive crystals and polymers
10. Computer generated holograms
- a. Detour phase encoding
 - b. Interferometric encoding
 - c. Example problem
11. Digital Holography
- a. Recording and reconstructing holograms on digital cameras
 - b. Resolution and recording requirements
 - c. Digital holographic microscope
 - d. Holographic optical sectioning
12. Optical Data Storage
- a. System metrics: M#, material sensitivity
 - b. Fourier transform configurations
 - c. Multiplexing schemes
 - d. Photorefractive and disk systems
 - e. Phase masks
 - f. Associative Memory Systems
13. Other Applications
- a. Fiber Bragg gratings
 - b. Displays
 - c. Holographic spectrum splitting systems

- d. Holographic solar concentrators
- e. Volume holographic imaging

14. Introduction to photonic bandgap materials and devices (as time permits)

- a. Effective medium theory
- b. Resonance mode grating filters
- c. Photonic Bandgap materials
- d. Device structures

Labs: Several experiments will be conducted for you to go through the process of recording and characterizing holograms. A new polymer is available for recording holograms. Lab write ups will be short.

Class Paper:

Students will be required to review a current research paper from a peer reviewed journal, write a short summary paper, and give a ten minute presentation in class on the content of this paper.