OPTI/ECE 527 (Fall 2022)
Diffractive Optics and Holographic Principles

Instructor: *Yuzuru Takashima, Ph.D., Professor*
Class Hours: *Tu/Th 9:30-10:45;* **Room:** *OSC 305*
Office: *Meinel 627;*
Office Hours: *Tuesday*: 10:45-11:30 in person or over Zoom (see D2L)
If you plan to attend office hour over zoom, please email me in advance to schedule meeting on time.
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Office Hours: TBD

Grading:
HWKs (~6): *20%*
Mid Term Exam: *35%* (Mid October)
Class Paper: *10%* (Last week of class)
Final Exam: *35%*

100%-90%: A | 75%-89%: B | 65%-74%: C | 55%-64%: D | 0%-54%: E

The class overviews and discuss theory and analysis of light matter interaction including holography, diffractive optics, and photonics crystals. Analysis frameworks such as Fourier optics, approximated coupled wave analysis, and rigorous coupled wave analysis. In particular for holography we overview basic principles, recording and reconstruction process, spatial frequency analysis, Fourier analysis of gratings, image analysis of holograms, requirements for holographic recording, recording materials, computer generated holograms, digital holography and applications including, laser beam steering, holographic data storage, holographic image guide for AR devices, fiber Bragg gratings, holographic displays, holographic spectrum splitting systems, and holographic solar concentrators.

Text Books: Available on line
Note: *The book by Goodman is highly recommended and the new book by Toal also provides a good overview.*
Required
1. R. K. Kostuk, "Holography: Principles and Applications," CRC Press, 2020. Available online.
2. J. W. Goodman, "Introduction to Fourier Optics, 3rd ed." McGraw Hill, 2005. Available online.

Recommended

3. H. Coufal, D. Psaltis, and G. Sincerbox, "Holographic Data Storage," Springer, 2000. Available online.

4. V. Toal, “Introduction to Holography,” CRC Press, 2011. Available online.

Required Software:
Rsoft (available online)
https://wp.optics.arizona.edu/helpdesk/osc-site-licensed-software/

Lecture Content:

1. Basic concepts
    a. Differences between holographic and intensity imaging
    b. Holographic recording and reconstruction process
    c. Normal and conjugate reconstruction
    d. Grating equation

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. Sequential and simultaneous hologram multiplexing
    i. Wavelength and angular selectivity of volume holograms
    j. Effects of absorption during construction

9. Rigorous Coupled Wave Analysis
    a. Theory
    b. Software practice

10. Holographic materials –recent developments
    a. Silver halide films
    b. Dichromated gelatin
    c. Holographic photopolymers
    d. Photoresists
    e. Photorefractive crystals and polymers

11. Computer generated holograms
    a. Detour phase encoding
    b. Interferometric encoding
    c. Example problem
    d. CGH calculation
    e. Recent development of Spatial Light Modulators

12. Digital Holography
    a. Recording and reconstructing holograms on digital cameras
    b. Resolution and recording requirements
    c. Digital holographic microscope
    d. Holographic optical sectioning

13. Applications

a. Laser beam steering
b. Holographic Data Storage
c. Holographic Image Guide for AR devices
d. Fiber Bragg gratings
e. Holographic Displays
f. Holographic spectrum splitting systems
g. Holographic solar concentrators
h. Volume holographic imaging

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

Class Paper:
Students will be required to review a current research paper from a peer reviewed journal and write a short summary (3-4 pages) on the content of this paper.

Grading policy:
All problem sets and design projects are to be turned in to D2L on the date due (by 5:00 pm). Late homework will be marked off by 50%. No late turn in is allowed after 1 week of the due date. All homework, exams, design projects, etc., must include your **name, and course number (OPTI 527) as header, and page number at bottom, deliverables without that information is -5pt deduction of grading**. Must be done on one side of an 8½ x 11 sheets of paper. Scan and uploaded in a single PDF format. Figures and answers, if handwritten, must be readable. Submission in a form of separate pictures, such as jpeg, bmp format will not be graded.

No re-grading after one week from the day the solution is posted (i.e., solution posted on Monday, students need to complete regrading by following Sunday). We consider late turn in of assignments to accommodate students' academic, family and health needs only if students obtained ***a prior permission*** from the instructor.

Accessibility and Accommodations:
It is the University's goal that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability or pregnancy, please let me know immediately so that we can discuss options. You are also welcomed to contact Disability Resources (520-621-3268) to establish reasonable accommodations.
Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.