OPT 461 — Fourier Optics — Syllabus 2022
Draft 8/19/22

Description: The principles of physical optics including diffraction and propagation based on Fourier transform theory; Fourier mathematics; integral formulation of electromagnetic propagation; diffraction from apertures and scattering objects; sampling theory; propagation through optical systems; transforming; coherent and incoherent imaging; impulse response, optical transfer function; optical filtering; holography; and selected topics of current research interest.

Class Location: Wilmot 116

Class Time: Mon. & Wed. 10:25am-11:40am;
Lectures are given in person during the normal class time.
If remote learning becomes necessary, **then** Students will participate with a combination of synchronous live lectures by Zoom and watch pre-recorded lectures asynchronously before class time and then use the class time for a synchronous Questions/Answers/Discussions. Possibly a TA will be physically present in the classroom to facilitate that for the students who can be physically present. Students not physically present can participate remotely via Zoom.

Notes on 2022 classes:
Classes begin Wednesday, Aug. 31.There is no class on Labor Day, Monday September 5. Fall break (no classes) on Monday Oct. 10 (and Tues. Oct. 11).
Most likely no class on Wednesday, Nov. 25 (day before Thanksgiving). Last day of classes is Wednesday, Dec. 14. The 3-hour final exam will be the following week, TBD.

Recitation Time: 12:30 pm -1:30pm Fridays in Wilmot 116 (optional)

Textbook:
J.W. Goodman, ***Introduction to Fourier Optics,*** **4th** *Ed.* (W.H. Freeman & Co., 2017).
The 4th edition is significantly changed; earlier editions will not work.

Topics Covered: (for the most part: Goodman's Chapters 1–8 + Appendices A&B, parts of Chs. 9-11 + handouts)

Topics for Fall 2022 (this might have to be adjusted as the semester progresses):

Module 1. Course Overview
- Syllabus
- Examples of Diffraction

Module 2. Fourier Transform Mathematics (Ch. 2 & Appendix A)
- Linear systems theory
- Basis sets
- Fourier theorems

- Fourier transform pairs
- Convolution
- Sampling theory
- Discrete Fourier transform
- Space-bandwidth product
- Phase retrieval (later in sequence)

Module 3. Diffraction and Free-Space Propagation (Chs. 3-5)

- Wave and Helmholtz Eqs.
- Angular spectrum approach
- Evanescent waves
- Huygens-Fresnel principle
- Rayleigh-Sommerfeld diffraction
- The importance of phase
- Fresnel (near field) diffraction
- Fraunhofer (far field) diffraction
- Diffraction gratings
- Talbot imaging
- Discrete Fourier and Fresnel propagation

Module 4. Propagation through Optical Systems (Ch. 6)

- Lens transmittance function
- Fourier transformation using lenses
- Coherent imaging and impulse response (single lens)
- ABCD matrix optics (Appendix B)
- Fermat's principle
- Propagation though a general ABCD system

Module 5. Frequency Analysis of Imaging Systems (Ch. 7)

- Abbe theory
- Generalized coherent and incoherent imaging and spatial coherence
- Optical Transfer Function and apertures
- Resolution
- Aberrations and generalized pupil function
- Apodization
- Coherent versus incoherent imaging
- Speckle

Module 6. Selected Applications

- Image Reconstruction
    - Inverse and Wiener filtering (Ch. 10.6.1-2)
- PSF and Transfer Function Engineering
    - Exoplanet imaging (Ch. 8.3)
- Optical Information Processing (Ch. 10.1)
- Holography (Ch. 11.1–11.6)

There may be a possible guest lecture on a special topic if the opportunity arises.

Instructional Activities

- **Lectures during class time**
  On average, we should cover about 10 pages in the book and about 10 pages of the lecture slides per class time; but there is a large variability in the number of pages. Note that the lecture slides are there to provide organization, equations, diagrams, and images; by themselves they are meant to be very incomplete; the words spoken and extra sketches that might be presented are needed for completeness. The required **readings** will be discussed at the beginning of each chapter of the book.

- ***If remote learning becomes necessary, then***
  - There will be a combination of (a) synchronous lectures by Zoom at the regular class time and (b) pre-recorded **videos** followed by synchronous Zoom **Question/Answer/Discussion (QuAD**) sessions
  - **If Videos:** Watch the **videos** of the assigned lectures and read the assigned **readings** by their due dates. Lectures will be pre-recorded and students will view them asynchronously on Blackboard (via Panopto).
  - **QuADs:** After having watched the assigned lectures, attend and participate in the associated **QuAD sessions**, which will be held during the class time periods (Monday and Wednesday, 10:25 am – 11:40 am Eastern time, in Wilmot 116). Attendance is expected. They should be in-person in the classroom for students who can come but remote for the faculty and for students who cannot be there physically. The faculty and the students who are remote will participate synchronously, via Zoom (use the link in Blackboard). Students may submit questions to the faculty ahead of time. After those are discussed, students may also ask additional questions or engage in additional topics of discussion during the session. Participation in the QuADs (ask questions, contribute to discussions) will be reflected in the class participation portion of your grade. Additional material that arises from discussions during the QuADs can be included in the exams.

- **Message boards**: Students may post questions on Blackboard.

- **Recitations:** There will be in-person **recitations** (on Fridays, 12:30 pm – 1:30 pm Eastern time, in Wilmot 116) lead by a TA. Recitations are optional; they are not required but are an additional service to the students who wish to attend them.

- **Faculty office hours:** The faculty will have drop-in **office hours** at the posted time (Thursdays at 4:00-5:00 pm Eastern time); in addition, appointments can be made for other times; send a request to the faculty by email.

- **TA office hours:** A TA will have **in-person office hours** at the posted time (TBD, usually on Tuesdays); in addition, appointments can be made for other times. If an

emailed question can be answered by email, the TA will try to answer it within 24 hours.

- **Study groups:** Students experience greater success by joining small study groups. You can learn from the readings, from your teacher, from the TA's, and from your peers. An effective way to learn something more deeply is to explain it to another student. Students will self-assemble in study groups, which can be in-person, via Zoom, or via a chat application such as Slack.

- **Additional help:** For help with studying more effectively and for tutoring, contact The Center for Excellence in Teaching and Learning (CETL), cetl@rochester.edu, (585) 275-9049, Dewey 1-154.

- **Be safe:** Follow the University of Rochester requirements, whether they involve wearing a mask or social distancing (as of this writing: no masks required). This is mandatory for all in-person interactions. Your good health is critical to doing well in the course.

- **Homeworks:** Homeworks will typically be assigned each Wednesday and will be due at 10:25 am Eastern time the following Wednesday. You do not really understand the material until you put it into practice by solving problems. Scan you homework solutions and upload them to Blackboard.

- **Exams:** There will be one mid-term exam. It will cover the material discussed up to the date of the exam. It will be held in person during the regularly scheduled class time, a Monday or a Wednesday at 10:25-1:40 am, Eastern time, in Wilmot 116. The three-hour final exam will be comprehensive but emphasize the material covered after the mid-term exam. The students will and scan their answers and upload them into Gradescope and hand in their solutions in a bluebook. The exams will be closed book. No electronic devices will be allowed except possibly for the purpose of downloading the exam, uploading the answers, and communicating with the proctor of the exam. For each exam, the students shall put together a one page or two pages of notes on 8.5 x 11-inch sheets of paper, and print it out. The notes can include any text, equations, diagrams, etc., hand-drawn or produced by a computer. During an exam, the student can use their sheet of notes for that exam and, for the final, the sheets of notes for the mid-term exam. The student will sign and upload the sheet of notes for that exam along with their answers to the exam. The quality of the sheets of notes will be given a grade of 1% of the total course grade if the sheet is at least half filled with material, or 0% if less than that. Each student should produce their own set of notes independently, since the preparation of the notes is a valuable learning tool.

Assessments: Grading

- 20% Weekly homeworks due at beginning of class on due date
  - Lose 10% of grade on that homework each day it is not handed in

    - e.g., lose 10% after class, 20% if handed in 25 hours late
- 30% Mid-term exam
- 44% Final (comprehensive) exam
- 5% Class participation
    - Class attendance is expected
    - Ask questions and contribute to discussions
- 1% Sheets of notes for all exams
- Extra credit for discovering errors in the course textbook

Academic Honesty for OPT 461

— **Academic Honesty** policies will be enforced. Read the University of Rochester's policies on Academic Honesty. In addition, specific to OPT 461 are the following policies.

— Exams

For exams, you will be asked to write, on the first page of your answers, the following, as required by the Dean of Graduate Studies: "I affirm that I will not give or receive any unauthorized help on this exam, and that all work will be my own.", and write your name after that.

— Homeworks

- In OPT 461, working together is encouraged, and giving one another hints on homework problems is acceptable.
- Each student should write down his/her homework separately without looking at others'.
- Copying another's homework or copying from any other source or letting another copy your homework is plagiarism (falsely claiming someone else's work to be your own) and is forbidden.
- Homework is a small part of your grade. Think of the homework problems as practicing for the exams. If you cannot do the homework problems yourself, you will do poorly in the exams, which together count for much more.

— Distribution of lecture videos, lecture slides, homeworks

The lecture videos (if any), the slides from the lectures, and the homework assignments and solutions are only for the students taking OPT 461 or by permission of the faculty. Posting them on a web site or allowing an unauthorized person to gain access to them is forbidden. These are all copyrighted materials. Unauthorized distribution will be considered a violation of academic honesty.

"Derive" and Mathematica™

For both homeworks and exams:

- When "proving" or "deriving" something for homeworks and exams
    - Show the detailed intermediate steps

  - Showing how you get to the answer is more important than getting the right answer
- Using Mathematica™ (or Maple™, etc.) for homework problems
  - You may not use it to get a result (solve equations) and then just report that result
  - Do show detailed intermediate steps
  - You can use Mathematica™ to check your results
  - You can use any software to make plots, images

Additional readings: The following are not required but might be useful to you if you want to see some similar material from a different perspective or go into more detail on some topics:

Call Number	Author	Title	Comment
QC355.2 .G37	J.D. Gaskill	*Linear Systems, Fourier Transforms, and Optics*	Similar material from a different perspective
SPIE Digital Library	J.W. Goodman	*Fourier Transforms Using Mathematica*	Great for Fourier math and Mathemetica
QA403.5 .B7 1986	R.N. Bracewell	*The Fourier Transform and Its Applications*	Fourier transform math classic
TA1675 .S5	A.E. Siegman	*Lasers*	ABCD propagation

Siegman's *Lasers* is available as a free download:
https://www.osapublishing.org/books/bookshelf/lasers.cfm