PHYS399O: Introduction to Computational Fourier Optics

Course Description

The utility of optics in modern physics experiments is uncontested. Introducing a more detailed model of optical phenomena will necessarily require more difficult computations. It also clears up many questions unanswered by ray optics. This course goes over basic computational methods (Fourier Optics). Students will understand and implement a small collection of Fourier optical propagation algorithms in python3 or MATLAB. Students will additionally be exposed to some experimental considerations in their models, and common plotting schemes for optical simulations. Skeleton code will often be provided, that way students are allowed to focus on physical and mathematical details of computing implementation and interpretation. As a final project students will simulate a laser cavity system to gain understanding (no pun intended).

Course Details

- **Course**: PHYS399O
- **Prerequisites**: PHYS375, PHYS165/265 alternatively ENEE381/382 and ENEE150, or equivalent experience.
- **Credits**: 1
- **Seats**: 10
- **Lecture Time**: Friday 11:00am-11:50am
- **Location**: PHY1219
- **Semester**: Fall 2024
- **Textbook**: Computational Fourier Optics: A MATLAB Tutorial, Voelz
- **Course Facilitator(s)**: Benjamin Schreyer
- **Faculty Advisor**: Thomas M. Antonsen

Topics Covered*

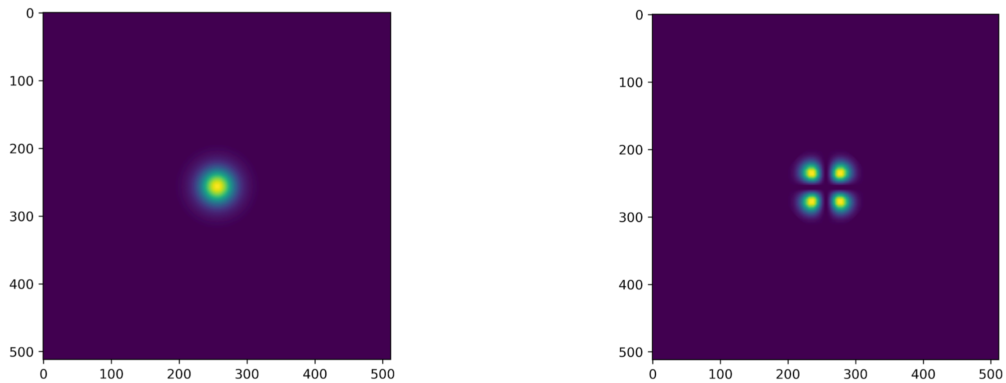
Syllabus may be subject to minor changes, but drastic revisions will require input of students/facilitators, and those involved will be notified immediately

- Diffraction to the far field
  - Refresh
  - Synthesis, general far field diffraction
  - Aperture at measurement plane
- Programming
  - Using programming packages for linear algebra computation and FFT
  - Statistical moment calculations (for beam width)
- Moments of a beam, width and centroid
  - Motivation
- Fresnel kernel
  - Two dimensional formulation/separability, transverse shift invariance
  - Single FT expression
  - Near field coordinates
  - Formulation
  - Tractable problems
- Lensing, other components, parabolic propagation
  - Model of a thin lens
  - Diffraction with lensing
  - Parabolic propagation
  - Mirrors, tip/tilt
- Astronomical imaging
  - “Imaging the angle”
  - Atmospheric/turbulence phasing
  - Point spread function
- Lab optics
  - Transverse modes
  - Collimation
  - Two lens system
  - Simple gain media

Final project: Laser cavity transverse modes:

Students will model a cavity based laser to determine effect of cavity geometry generally including optical aberrations, different cavity schemes and gain media. Students will apply back to back propagations on nontrivial lensing specifications to model the cavity.

Extra credit: Measure the beam quality for the output beams by using a parabolic fit. Discuss how the quality and various geometries are roughly related.



Low order laser beam forms created by two different aperture geometries on a laser cavity

Schedule*

CHW Coding homework
I aim to make readings, except for the first day, optional. Since the course is one credit, paying attention to lecture, and completing exercises should meet learning goals.

Week	Topic	Assignment
1 (8/26)	Syllabus Assumption for the double slit (Huygens) Maxwell’s equations to scalar wave equation: point sources plane boundaries steady state	Assigned: HW1, Fraunhofer approximation and generalized slit diffraction Assigned: Install Python, Jupyter Notebooks, Numpy, Matplotlib or install MATLAB Morin, Waves Ch. 8: Maxwell’s equations to wave equation Morin, Waves Ch. 9: Diffraction
2 (9/2)	Fourier transform in the far field diffraction integral.	Due: HW1 Assigned: CHW1, creating and visualizing a complex field, 1d diffraction.

	Intensity and phase in numpy, basic sampling, coordinate fields. DFT in code	Voelz ch.3 Voelz p.55
3 (9/9)	Changing coordinates scale, relation to the inverse square law Apertures, the convolution Overview of useful DFT properties, shift, theorem, inversion.	Due: CHW1 Assigned:CHW2 Convolving for apertures Assigned: Quiz on diffraction, coding 9/23 Voelz ch.2.4
4 (9/16)	Sampling and support Discrete convolution theorem and shift theorem	Due: CHW2 Assigned: CHW3, FFT shift, shift theorem Voelz p.24
5 (9/23)	Fresnel approx/coordinates single FT code Separability of 2d diffraction	Due:CHW3 Assigned: CHW4 Fresnel propagation comparing the Fresnel FFT propagation and Fraunhofer FFT propagation. Quiz on diffraction, coding (Rescheduled to October 4th)
6 (9/30)	Code for 2d Fresnel FT Plotting of 2d amplitudes Mirrors	Assigned: HW2 2d FT Properties (convolution theorem for continuous and product transforms) Quiz on diffraction, comparing the near and far field
7 (10/7)	Gaussian beam Widths Lensing: ray optics vs wave optics	Due: CHW4 Assigned: CHW5 Width calculation
8 (10/14)	Lensing wave optics: Uncertainty principle and “running photons”	Due: HW2, 2d Fourier transforms Due: CHW5 Assigned: CHW6, Lensing calculations, diff. Wavelengths

		Assigned: Quiz on thin lens Voelz ch.4.3
9 (10/21)	Green's functions(Huygen's), transfer functions applied to the Fresnel propagation	Voelz ch.6 Quiz thin lens
10 (10/28)	Numerical formulation of the transfer function Parabolic propagation Fresnel prop in 2d, transfer function	Due: CHW6 Assigned: CHW7, M2 model Voelz ch.5
11 (11/4)	Transfer function and amplitude sampling, aliasing Periodic boundary Rayleigh-Sommerfeld impractical Reminder: Fresnel approximation	Due: CHW7 Assigned: Final Project Voelz ch.5
12 (11/11)	Laser cavity Transverse modes Collimation Beam quality	
13 (11/18)	THANKSGIVING	

14 (11/25)	Atmospheric aberrations, what is turbulence, two kick A telescope is a Fourier transform Babinet's principle Starshades Phase domination of aberration modeling	Due: Checkpoint Final Project
15 (12/2)	Buffer/guest in nonlinear optics/other	Due: Dec. 8th Final project

*Note that this is a tentative schedule, and you have flexibility as an instructor to modify when assignments are assigned and due, as well as (limited) leeway on when the midterm will happen. All finals/final assignments **must** happen/be due during the last class so as to avoid hosting a final during finals week.

Grading

Grades will be maintained on (ELMS/department grade server/etc). You will be responsible for all material discussed in lecture as well as other standard means of communication (Piazza, email announcements, etc.), including but not limited to deadlines, policies, assignment changes, etc.

Any request for reconsideration of any grading on coursework must be submitted within one week of when it is returned. No requests will be considered afterwards.

Your final course grade will be determined according to the following percentages:

Percentage	Title	Description
10%	HW	A few homework assignments on math of Fourier optics and formulation for physical systems.
20%	Quizzes	Three quizzes throughout the semester to gauge understanding.

30%	Final Project	Semi comprehensive project on Fresnel Sommerfeld diffraction. Applied to astronomy, high power systems, or student proposed topic.
40%	Projects (CHW)	Coding projects during the semester. Implementing mathematical calculations for various optics simulations. Build up to the final project.

Communicating with course staff

Other means of communication have not been chosen as of now.
Interaction beyond the classroom is encouraged, but should be limited to important or more urgent issues. Topics that need not be addressed immediately can wait till class time.

Instructor(s) Name(s) and Email(s):

- Thomas M. Antonsen:

Facilitator(s) Name(s) and Email(s):

- Benjamin Schreyer:,

Excused Absence and Academic Accommodations

See the section titled "Attendance, Absences, or Missed Assignments" available at [Course Related Policies.]

Disability Support Accommodations

See the section titled "Accessibility" available at [Course Related Policies].

Academic Integrity

Note that academic dishonesty includes not only cheating, fabrication, and plagiarism, but also includes helping other students commit acts of academic dishonesty by allowing them to obtain copies of your work. In short, all submitted work must be your own. Cases of academic dishonesty will be pursued to the fullest extent possible as stipulated by the Office of Student Conduct. It is very important for you to be aware of the consequences of cheating, fabrication, facilitation, and plagiarism. For more information on the Code of Academic Integrity or the Student Honor Council, please visit http://www.shc.umd.edu.

Course Evaluations

If you have a suggestion for improving this class, don't hesitate to tell the instructor or TAs during the semester. At the end of the semester, please don't forget to provide your feedback using the campus-wide CourseEvalUM system. Your comments will help make this class better.

Thanks to the CS professors at the University of Maryland, College Park for the basic syllabus outline.