ECEN 6006 SYLLABUS

NUMERICAL METHODS IN PHOTONICS

FALL 2022

INSTRUCTOR	ROBERT MCLEOD, MCLEOD@COLORADO.EDU
OFFICE HOURS	FRIDAY 1 PM AND AFTER CLASS TU/TH AS NEEDED.
	SEEC N321F AND https://cuboulder.zoom.us/j/6300028907
MEETING TIME	TUESDAY / THURSDAY AT 3:30 PM
MEETING LOCATION	ECEE 265

OBJECTIVES

Optical systems employ a rich array of physical effects which are described by well-understood equations. However, for all but the simplest devices these equations are typically too complex to permit closed-form solutions. Numerical methods are thus both essential and powerful for predicting the performance of photonic devices. The goal of this class is to enable students to create their own tools customized to specific needs as well as understand the operation and limitation of algorithms used in existing packages.

The course will develop your ability to rapidly create and exercise numerical design tools. There will be no traditional homework or tests, instead students code and apply a series of different numerical tools. These include finite difference time domain, beam propagation, projection tomography, and coupled modes. By the end of the semester, students will thus have both a full toolkit of computational methods and also the well-practiced ability to create them as needed.

Specifically, at the end of this class you will:

- know of a broad range of computational tools and be able to select the best for any particular application,
- be able to rapidly write your own tools specific to your needs,
- understand the limits of various methods in order to make best use of your own or commercial packages,
- be able to couple numerical methods to optimization to create powerful design tools,
- have a better understanding of optics in general by simulating and visualizing a number of relevant optical phenomenon.

Feedback

Things go wrong. Help make it right by telling me your opinion. I will always welcome your feedback, even if you are critical of my performance. Additionally, the link below provides an anonymous way for you to tell the department about any issue that you feel warrants attention.

https://www.colorado.edu/ecee/electrical-computer-energy-engineering-feedback

Schedule (subject to change due to apocalypse)

Week of	Lecture	HW	Due	Topic
22-Aug	1			Introduction
	2			EM background
29-Aug	3	1 FDTD		Finite differences
	4			FDTD method
5-Sep	5			Radiation boundary conditions
	6			Advanced FDTD algorithms
12-Sep	7			Fourier modes in infinite space
	8		18-Sep	The Booker quartic
19-Sep	9	2 FFP		Transfer function of free space
	10			Fourier propagation
26-Sep	11			Fourier propagation
	12		2-Oct	K space
3-Oct	13	3 K-space and tomography		K space
	14			K space
10-Oct	15			Coherent transfer function
	16			Projection tomography
17-Oct	17			Beam propagation method
	18		23-Oct	Beam propagation method
24-Oct	19	4 BPM		Beam propagation method
	20			Beam propagation method
31-Oct	21			Waveguides
	22		6-Nov	Waveguides via BPM
7-Nov	23	5 Modal prop and CM		Eigemmode expansion propagation
	24			Coupled modes derivation
14-Nov	25			Coupled modes examples
	26			Multilayers and Block modes
21-Nov				Fall break
				Fall break
28-Nov	27			Student presentations
	28			Student presentations
5-Dec	29		11-Dec	Student presentations

CLASS STRUCTURE

COMPUTER USE

This is fundamentally a laboratory class, where the lab is your computer. Just like a lab class, you will learn new theoretical concepts while simultaneously honing your lab skills. In this case, those skills are numerical programming methods.

- Obviously, you will need access to a computer. It does not need to have significant memory or power, but needs to be more than a chromebook. The operating system doesn't matter.
- Second, you need a programming language with mathematical functions and graphics. Matlab, Mathematica, IDL and Python (with appropriate libraries) are examples. I recommend matlab but can help you debug the others in that order of my competence. You are free to use something else, but my ability to help you debug will suffer. As a CU student, you have site licenses to such software. It can be found here: https://oit.colorado.edu/software-hardware/software-catalog
- Finally, you need to write up results including sophisticated graphics and technical language. That requires both software and the experience of technical communication. If you are weak on the latter, you should take advantage of CU services like the writing center (https://www.colorado.edu/program/writingcenter/) or have others proof-read your work. Numerical methods are a powerful way to communicate scientific concepts and this communication is a required part of the class.

ATTENDANCE

We will do simple derivations and other activities in class to learn the fundamental concepts. Additional details are in the class notes. However, since there is no textbook and the provided notes are not intended to replace one, **it is critical that you attend class.**

HOMEWORK

This is an advanced graduate class with no exams. That means that the workload for the HW projects is significant. Success will require you to stay focused on each project as soon as it is assigned (see the HW column in the schedule). There are five HW projects with due dates in the schedule above. Due dates are generally a week after we finish discussing the associated method. It is thus critical that you begin work on each project as soon as the previous one is finished. **There will generally not be time for you to complete projects if you start only after we finish all discussion on the method**. Here are suggestions for success:

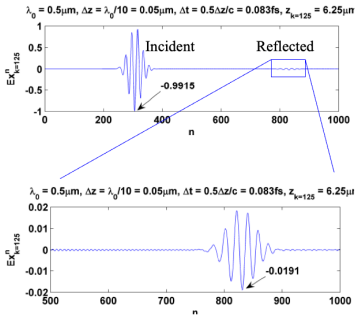
- When you turn in one HW assignment, immediately download the next. Read through it and try to understand what is being asked. This will prime you to identify key concepts when discussed in class.

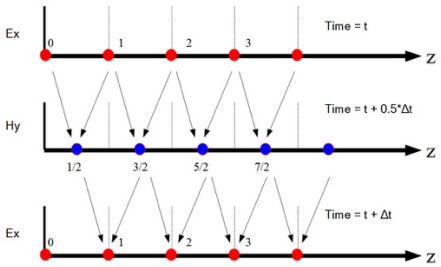
- As we start a new method, I will frame the structure of the code including areas that will require particular attention. Start working on these immediately so that you have a structured code with holes to be filled by the lecture materials.
- Work with others in the class. Code your own materials, while helping each other understand and formulate algorithms. Compare results.
- Come to office hours.

You will document your results in an IEEE letter-style paper, because writing in technical style is just good practice. **Write this paper from as if this is the first paper documenting the method and you are introducing it to the community**. Do not write a novel. Do briefly describe the mathematical foundation, any relevant implantation details (the language you coded in is rarely one of those), and the performance. The last section is where you will answer any questions posed in the assignment.

The grading rubric (out of 16.7 points per assignment)

- **2 Code**: internal documentation, neatness, clarity– this is the equivalent of your lab notebook for an experimental class.
- **5 Report**: Writing is professional, figures are clear. Just like always, graphs need axes (in physical units, not array indices) captions etc.
- **2 Function**: Your code works, as demonstrated in validation problems or checks.
- **1 Application**: You used the code correctly (proper parameters, sampling density, etc). This is an oft-overlooked pitfall.
- **5 Results**. You completed the requested assignment. Also, difficulty of problems attacked, creativity in approach, capability of results.
- **1.67 Reader's choice**: Creative and cool documentation or application of the method. Points awarded for how much I want to include your results in my notes for next year. Below are some examples of this, both copied from student reports.





INDIVIDUAL PROJECT

You learn the most when you apply class materials to an unstructured project. You are also all grad students with your own research and interests. The 6th assignment is thus an individual project where you extend one of the methods from class, the class notes, or the literature. It is very appropriate to apply this to your own research. In general, the scope should be like the HW

assignments. That includes both the level of effort and the implementation of a new method. That is, you should go beyond just applying one of the HW methods to your research.

This effort will proceed in parallel with the HW assignments, which means I need to help you stay focused. Each of the HW 1-4 will thus have a project milestone to prod you. You will present your results to the class at the end of the session. Grading, per the HW rubric, will be done on the presentation itself. No report will be turned in for the project to reduce workload at the busy end of the semester.

Exams

There will not be a midterm or final. Instead, proficiency with the course material will be developed and demonstrated by the numerical projects.

Grades and graded materials

Results for each of the HW assignments including a copy of your project presentation will be turned in on Canvas. The reports and presentations will be in PDF so that I can make grading comments on the built-in feedback tool. Grades will be posted to the canvas gradebook. Code samples will be uploaded in the native format. Each of the HW assignments and the project has equal weight, so counts for 16.7% of the total grade.

Communication

Please follow these guidelines to make our semester more efficient.

- **Personal, private issues**: Email me. You don't need to tell me you can't attend class – we're all adults here. You should ask a friend in class for a debrief, however.
- **Concept and implementation questions about HW**: Post these to the appropriate Canvas discussion board. Answer questions on this board if you can. If you email me such questions, I will move the discussion to Canvas with a delay that will increase as I get busy.
- **Class structure questions**: E.g. there's a dead link on the web-page. Post these to the "General" discussion board on Canvas.
- **The building is on fire:** Text or call my cell phone.

Classroom Behavior

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender

expression, veteran status, political affiliation or political philosophy. For more information, see the policies on classroom behavior and the Student Conduct & Conflict Resolution policies.

Requirements for COVID-19

As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

CU Boulder currently requires masks in classrooms and laboratories regardless of vaccination status. This requirement is a precaution to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office (contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office (contacttracing@colorado.edu).

Please inform me if, for any reason, you will have trouble attending class or completing assignments. Because of FERPA student privacy laws, you are not required to state the nature of an illness when alerting me. I will not require "doctor's notes" for classes missed due to illness.

Accommodation for Disabilities

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Preferred Student Names and Pronouns

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code academic integrity policy. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or email cureport@colorado.edu. Information about university policies, reporting options, and the support resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options. To learn more about reporting and support options for a variety of concerns, visit Don't Ignore It.

Religious Holidays

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance.

See the campus policy regarding religious observances for full details.